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ABSTRACT

The major ideas of this unit are: consistency and uniformity, cause and effect, and parsimony. Laboratory experiences consist of investigations into: projecting expectations, moon and stars, the relationships among different kinds of change (daily, monthly, annual temperature changes), force and motion, chemical reactions, superstitions, origin of the Earth, origin of life, pebbles, cobbles, boulders, and two theories of evolution. The laboratory experiences in this unit, as in all I-CLS units, are inquiry related and designed primarily to develop an understanding of how a scientist expects his world to behave. The format for each laboratory experience is as follows: Introduction, Materials and Equipment, Collecting Data, and Follow-up. (BP)

C. How a Scientist Expects His World to Behave

A scientist believes that the world which he has found is an orderly world. It follows definite patterns. The description of these patterns constitute natural laws. If there are things in the world that he does not understand, he expects that further discoveries will bring understanding, and that nothing will be brought to light that does not fit with the patterns already discovered.

Furthermore, if he were able to go out and explore the whole universe (other galaxies, other suns, other planetary systems) he believes that he would not find anything that followed a set of natural laws contrary to the natural laws that our world follows. New natural laws might be discovered with the accumulation of new knowledge, but these could be understood on the basis of what we already know.

A scientist expects the world to behave consistently and uniformly. He expects effects to result from discoverable causes, and that a particular cause will always be followed by the same or an understandably related effect. Science abhors unique events--things that happen (or happened) only once, and never again. Science attempts to explain the physical world without resorting to the occurrence of unique events, or events that occur without material causes.

I-CLS

Unit C. How a Scientist Expects His World to Behave

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Idea of Consistency and Uniformity C.1.

Idea Bridge: A Dependable and Predictable World

A scientist believes that the world which he has found is a dependable world. The discoverable past and the predictable future follow the same pattern as the observable present. Therefore he feels that he can discover the past and predict the future by studying and knowing the present.

From this concept comes the whole picture of the world and the universe that science has put together. All natural law is based on it. It has almost completely replaced the view of the world that was held before the days of modern science, in which magic and miracle played a major part. This change in view has taken place in the past 500 years; much of it in the past 100 or even 50 years.

LABORATORY EXPERIENCE C.1.a.

Projecting Our Expectations

Introduction:

If you put a book or an article of clothing in a particular place, why do you expect to find it there when you need it again? What is your reaction if you do not find it there? How do you explain its not being there? Why? You expect the sun to rise each morning, and you expect to find your house on the same side of the street as it was the night before. You expect the direction you take to go to school to be the same. It would be disconcerting if it were not.

Once there was a science fiction story based on the idea that the sun failed to rise one morning. If this were actually to happen, think of all the terrible things that would result from it, and the consternation that it would cause. Aside from all of these results, however, why would the failure of a regularly recurring common event like this be disconcerting?

Materials and Equipment:

Sites where erosion is taking place in nature (on the school ground, along roadsides, at construction sites, et cetera)

Maps showing drainage patterns

A relief model or map of North America

Sand table (if available)

Collecting Data:

In a typical day in your life, list the things that you normally depend on happening just as they have happened before. Why do you expect them to happen? How long have they happened in this way? What is the probability of their changing? A slow change? A sudden, abrupt change? Why? Why not?

What kinds of things do people in general expect to continue to happen as they have always happened? List as many of these things as you can think of. What is the Principle of Consistency? How is it related to the existence of natural laws? What would the world be like if it did not operate?

Observe the results of erosion caused by running water on a dirt pile or a cutbank at the edge of a road. Look for examples of water erosion at the site of new construction. Can you find any results of erosion on your school ground? Where else can you find such results?

Set up a sand table (if you have one available) in the laboratory, and use it to study the effects of water erosion. Make imaginary mountains, and see how erosion wears them down. (Note: This work with a sand table may be omitted if the effects of erosion have been observed outdoors.)

Study relief maps and models. How are stream valleys formed? What is the difference between a young valley and an old valley? Between a young stream and an old stream? Relate these things to the erosion effects that you have observed on a smaller scale. Do the same kinds of things take place in an eroded field take place on a larger scale in stream valleys?

Study a relief map of North America. Where are the youngest mountains? The oldest mountains? How do they differ from one another? How can you tell that one is older than the other? Why?

What is the Principle of Uniformity (Uniformitarianism)? How does it serve to explain the features of the landscape that we see around us? What are some examples of the operation of the Principle of Uniformity other than attempting to explain the development of the features of the earth's surface?

What is the relationship of the Principle of Uniformity to the Principle of Consistency? Are they different aspects of the same thing? Could we have one operating without the other? Why or why not?

Follow-Up:

Have you ever been in a town or other place after having been there one or more times before, and found yourself "turned around" or disoriented--that is, the streets appear to run in a different direction from the way you remembered them, or houses appear to have been "moved across the street," facing in a direction opposite to the way you remembered them. Usually the disorientation occurs most frequently if you come into the place at night, or if your second visit is in the daytime after you were there at night the first time. Why do you think this is? Sometimes also one may become disoriented on a cloudy day. Why?

Why is this experience an uncomfortable one? How is the disconcerting nature of it related to the Principle of Consistency?

Read Indian legends and stories about the origin of the Grand Canyon. How do scientists explain the origin of the Grand Canyon?

LABORATORY EXPERIENCE C.1.b.

The Moon and Stars

Introduction:

Astronomy is the oldest of the sciences. We have no way of knowing when man first observed the regular recurrence of the phases of the moon and the apparent movements of the stars, but we do know that some of the very earliest records that we have deal with the use of such observations to distinguish seasons and make primitive calendars. There is reason to believe that primitive man's first idea of a "year" was really a "moon." He marked the passage of time by counting lunar cycles (the changes of the moon's phases from the time it is "full" until it is "full" again) before he counted seasonal cycles (spring, summer, fall, winter) as we do now. In some parts of the world the seasonal changes are less clearly distinguishable. The phases of the moon are there for everybody to see.

The stars are there to see, too. Their patterns have always fascinated those who have looked at them. Primitive tribes all over the world made legends about them: the Big Dipper, the North Star, Orion, the Big Dog, the Seven Sisters, the Southern Cross and others. Their movements form the basis for accurately determining time through the 24-hour day, determining the exact length of the year, and the limits of the seasons. Early civilizations, the Babylonian in the Old World, and the Mayan in the Americas, did a surprisingly accurate job of constructing calendars, using astronomical data, even though they did not have the elaborate instruments for observing and measuring that are available to modern astronomers. In fact, the behavior of the sun, moon and stars constituted one of the earliest areas of nature in which man was able to observe and describe patterns, and in which the Idea of Consistency and Uniformity entered his thinking.

Materials and Equipment:

Diagrams of the phases of the moon (See accompanying page)

Diagrams of constellations (see accompanying pages)

Field glasses

A field guide to the stars, such as:

A Field Guide to Stars and Planets, by Donald H. Menzel.
Houghton Mifflin Company
Field Book of the Stars, Olcott, G.P. Putnam's Sons

Collecting Data:

This laboratory experience must be done outside the classroom on your own time. You may do it alone or in small groups. It may be done also in the form of a series of class field trips arranged in the evenings. The observations involved are necessarily limited to clear nights; therefore, it is difficult to plan the times of observations too far ahead.

The Lunar Cycle

Observe the changes in the appearance of the moon during a period of approximately one month, from the time the moon is full until it is full again. Identify the "new moon" (a crescent), first quarter (a half moon), gibbous moon(1), full moon, gibbous moon(2), last quarter (again a half moon), "old moon" (again a crescent). What is the "dark of the moon" (Note: This is sometimes called the new moon). Is this sequence always the same? What causes it? How long is a "day" and a "night" on the moon?

Observe the moon through field glasses during the different phases. Can you see any of the geography of the moon's surface? Plains? Craters? Mountains? Look particularly at the edge of the "day" or light portion, where it borders the "night" or dark portion. This line is called the "terminator." Can you see the shadows of any of the mountains at the edge of the "night" portion extending out into the "day" portion? Would it be possible to determine the height of these mountains? How?

The Stars

In connection with your observation of the moon, you can also identify a few constellations (groups of stars) and learn something about stars in general.

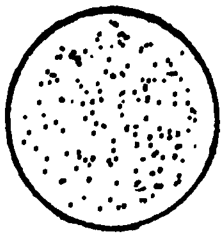
In the northern hemisphere, there are certain constellations that are readily visible at any time of the year. These are the constellations that rotate around the North Star, Polaris. It is called the "pole star" because it is located in the heavens very close to the point toward which the north pole of the earth points. If you were standing on the north pole, the star Polaris would appear to you to be at the zenith, directly over your head. Polaris is not visible to people living in the southern hemisphere. Why not? Is there a "south pole star? People in the northern hemisphere cannot see the most famous of the southern constellations, the Southern Cross.

The easiest way to locate Polaris is first to locate the Big Dipper (It is a part of a larger constellation called Ursa Major, or the Big Bear). Before you go out at night to find it in the sky, look at the diagrams of it on the accompanying page. Can you see that it really looks like a dipper? When you go out, face directly north, and look at the sky. Note: You will need to go to a place where the northern sky is not obscured by the lights of a city.

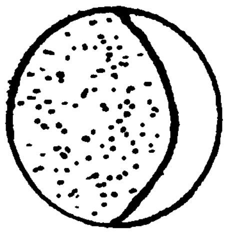
Locate the Big Dipper. Look closely and see if you can see that the star at the bend of the handle is really a double star, consisting of a bright star with a small, less bright companion close beside it. Then look at the two stars that form the front side of the bowl of the dipper. These are called the pointer stars, because they point almost directly to Polaris. Do you see Polaris now?

Would it be possible to determine the approximate latitude north of the equator of your position of observation by measuring the height of Polaris above the horizon? Why? How? Separate your index finger and your second finger as widely apart as you can, holding your other fingers down with your thumb. Now point your index finger at Polaris, with your second finger pointing below it. The distance between the tips of your two fingers is approximately five degrees on the earth's surface. Using this as a basis,

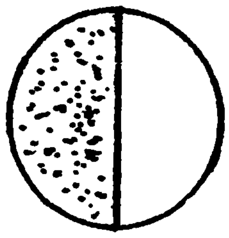
PHASES OF THE MOON



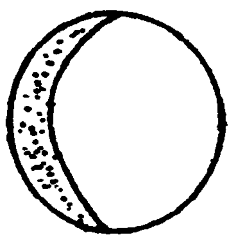
Unlighted moon (sometimes called the new moon)



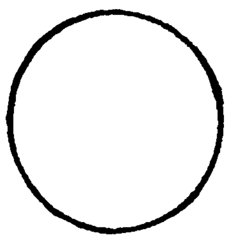
"New moon" (a crescent)



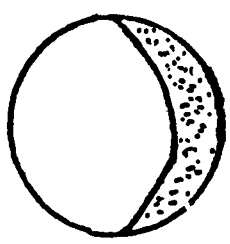
First quarter



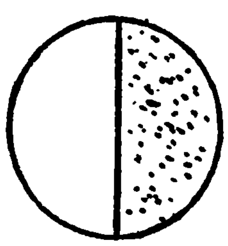
Gibbous moon (1)



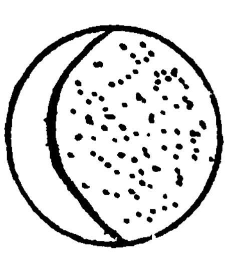
Full moon



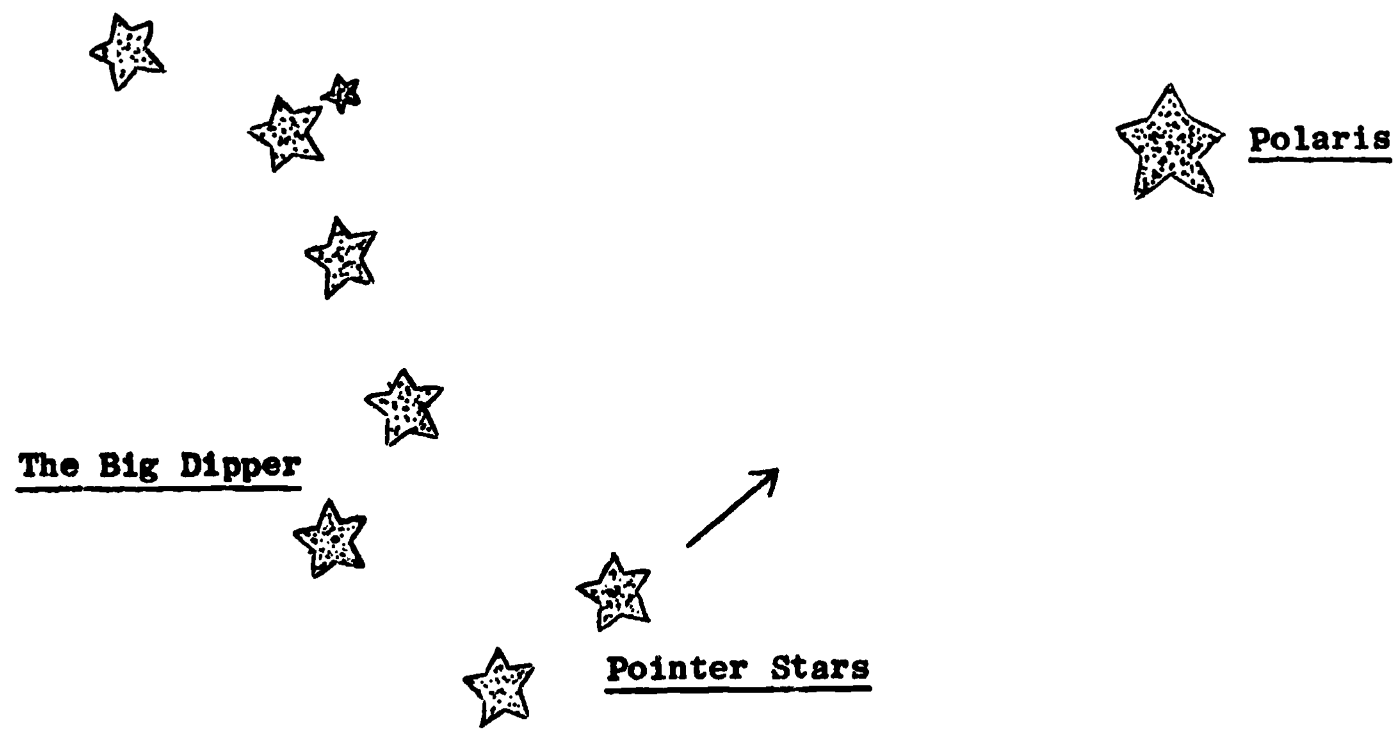
Gibbous moon (2)

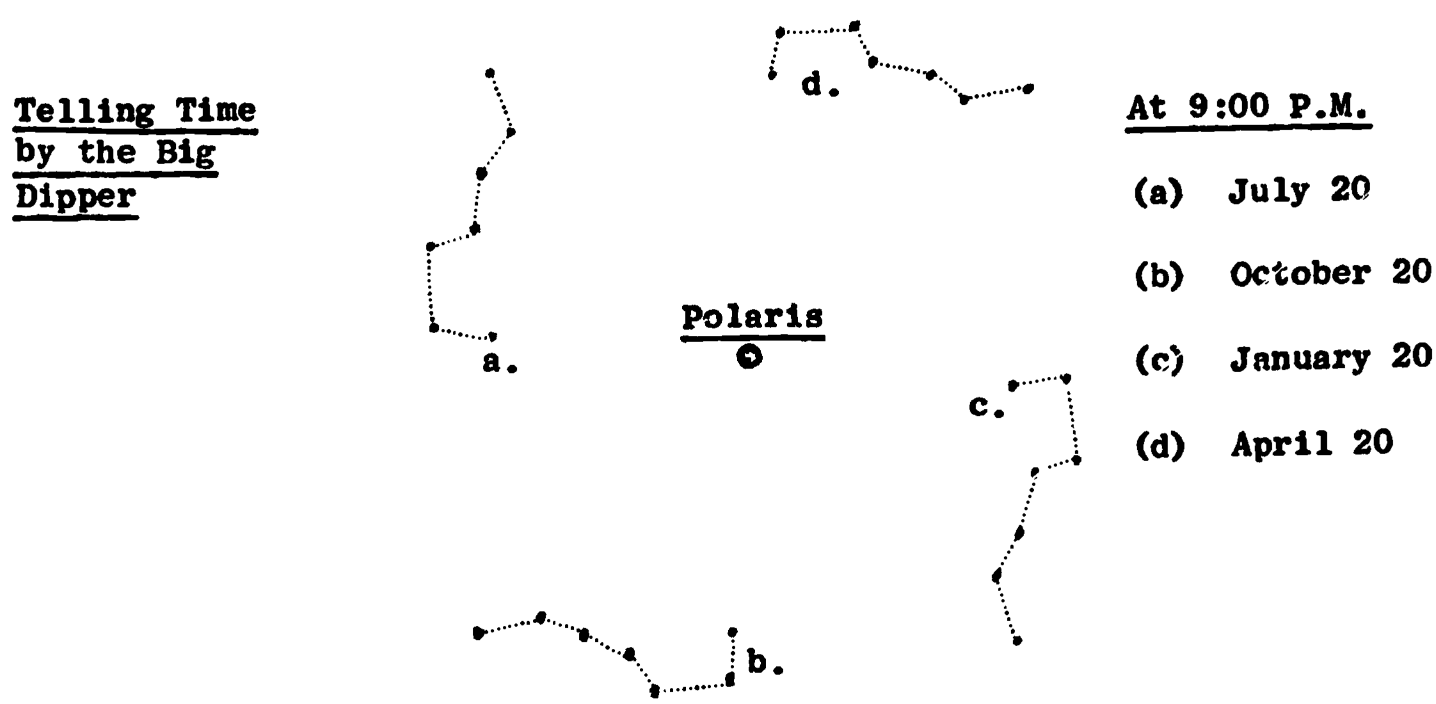


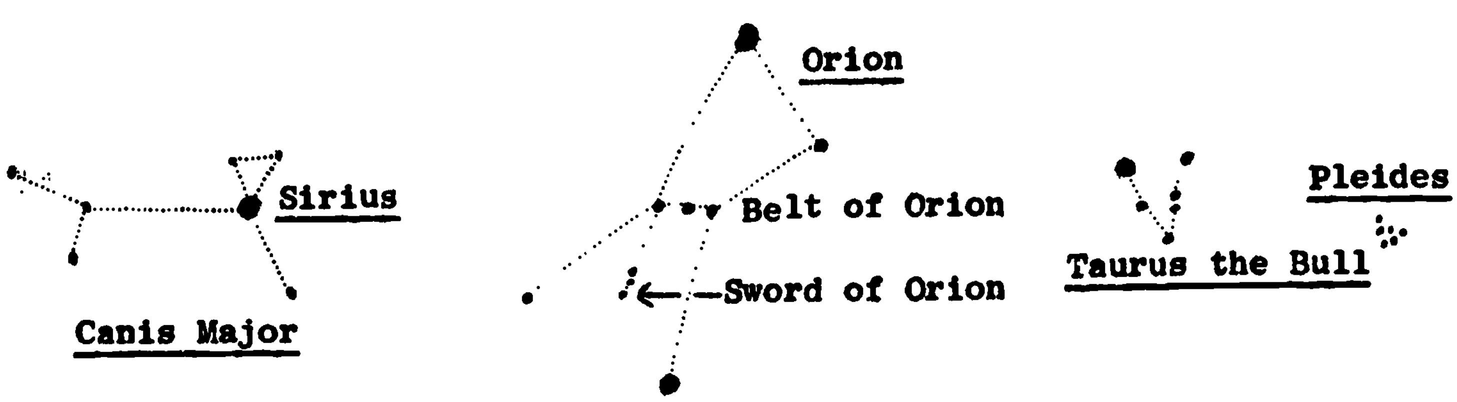
Last quarter



"Old moon" (a crescent)


Polaris
The Big Dipper
Pointer Stars


Telling Time by the Big Dipper
Polaris
a.
b.
c.
d.
At 9:00 P.M.
(a) July 20
(b) October 20
(c) January 20
(d) April 20


Orion
Sirius
Canis Major
Belt of Orion
Sword of Orion
Pleides
Taurus the Bull

estimate to the best of your ability the number of degrees from Polaris to the horizon. This should correspond to the number of degrees North Latitude of your position of observation. Look up your actual position. How close did you come with your estimate? Try again and see if you can improve your method of estimating. How were you able to do this?

It is possible to tell time by the position of the Big Dipper in relation to Polaris. Study the diagram on one of the accompanying pages which shows how the Dipper's position at various seasons of the year is related to clock time. Relate the Dipper's position at the season when you are observing it to clock time. Note: If the area where you are is on Daylight Saving Time rather than Standard Time, you will need to take this into consideration. How?

There are certain other constellations that are readily discoverable in the northern sky, once you have located the Big Dipper and Polaris. Use a field guide to the stars, and locate the Little Dipper (part of a larger constellation called Ursa Minor or the Little Bear); Cassiopeia or the Chair (the most conspicuous part of Cassiopeia consists of five stars which form a "W"); Cepheus, the King; Perseus, the Hero; and Pegasus, the Flying Horse. How many of these can you find? This group of constellations, along with the Big Dipper and Polaris, are sometimes called the Royal Family of the Northern Sky.

How do the patterns of behavior of heavenly bodies (sun, moon, and stars) point toward and reinforce the Idea of Consistency and Uniformity?

Follow-Up:

How do scientists think the craters on the moon were formed? Are there any similar craters on the earth? Where are they located? Why have they persisted on the moon while they have largely disappeared on the earth?

See how much you can find out about "moon signs" and moon superstitions. These have to do with planting things in the "light of the moon" or in the "dark of the moon," and other similar activities. Ask older people, particularly if they live now, or formerly lived in rural areas. Do you think there could be any real basis for these beliefs and sayings? Could you devise scientific tests for any of them? Try out some of them if you can do so. Are there natural phenomena (behavior of animals, physiology of humans, et cetera), that are known to be related to the moon or to the lunar cucle? What is the nature of moonlight that makes it different from sunlight?

How were some ancient religious beliefs related to the moon? Who were some ancient moon gods and goddesses? What stories and legends were built around them? What part has the moon played in literature? Find some examples of this. How would our literature and our art and music be less rich if it were not for the moon?

If you wish to learn more constellations in winter than those included in the Royal Family of the Northern Sky, there is a readily observable group that can be seen before midnight in the zone of the sky extending from the eastern horizon, more or less directly over head or slightly to the south of the zenith, toward the western horizon. These appear to "rise" and "set" like the sun and moon, earlier each evening and setting slightly later. If you were to look for them in the summer you would have to do so after midnight, or in the very early morning before daylight. Why?

The easiest constellation of this group to locate is Orion, also called the Hunter. Look at the diagram of it on one of the accompanying pages, and then try to find it and its companions: the Pleiades, also called the Seven Sisters, Taurus the Bull, and the very bright star Sirius, also called the Dog Star. Sirius is the brightest object in the heavens, other than the sun. It is part of a constellation called Canis Major or the Big Dog. Sirius forms the shoulder of the Dog. The head of the Dog is formed by an upside-down triangle of stars of which Sirius is the lowest point. The back of the dog, and the foreleg, hind leg and tail, consist of stars lying below and to the left of Sirius as you face south and look up.

This group of constellations is sometimes called the "Winter Procession." The Pleiades lie farthest toward the west, Taurus the Bull, containing a "V" lying on its side with a large red star at the point of the lower arm of the "V", follows the Pleiades. Orion is next, lying to the east of Taurus. The Big Dog lies still farther to the east, and down a little toward the southern horizon. See if you can locate the constellations of the Winter Procession. One legend says that Orion the Hunter, followed by his Dog, shot an arrow (the "V" in Taurus") which fell on its side, and then drank milk from the Milky Way using the Pleiades (also sometimes called a little dipper) as a cup. Can you see the "dipper" in the Pleiades?

What are stars really? How are they related to our sun? What is the Milky Way? Look for it on a dark, clear night. It is a bright, irregular band of low-degree brightness extending across the sky. Where is it located with relation to the zenith? What is a galaxy? What is the shape of our galaxy? Are there galaxies other than ours? How do we know?

LABORATORY EXPERIENCE C.1.c.

Relationships Among Different Kinds of Change:

Daily, Monthly and Annual Temperature Changes

Introduction:

Scientists expect the natural world to be dependable and predictable, but at the same time they recognize it to be a world of change. They expect the changes to be describable in some consistent fashion, and to show understandable patterns and relationships. Are there relationships between different kinds of change? Scientists try to discover and describe such relationships.

Some examples of change appear to be patternless, with the individual elements of change showing no apparent relationship to one another. Other examples appear to be progressive, moving in a specific direction. Still others show cyclic patterns, repeating themselves over and over again after longer or shorter periods. Is there any relationship between directional change and cyclic change? How are these patterned forms of change related to apparently patternless change? In this laboratory experience you will have an opportunity to study one example of the relationship of these different kinds of change to one another.

You know that the month of January is colder than the month of April, and that if you observe the temperature at the same time each day during either January or April, you will find that it varies in relation to the temperature of the days that precede it and follow it. You also know about changes through the seasons. The weather grows colder, then warmer as we go from fall, through winter, into spring and finally summer. These temperatures can be measured, and when a record is kept, the data show an interesting relationship between changes that are apparently patternless, and directional change and cyclic change.

Materials and Equipment:

Thermometer (either Fahrenheit or Centigrade)

Graph paper

Ruler

Collecting Data:

Every day, from the first of October to the first of May, at the same time each day, read the outdoor temperature in a place not exposed to direct sunlight. Record the temperatures of the days of each month on a graph:

Name of the Month

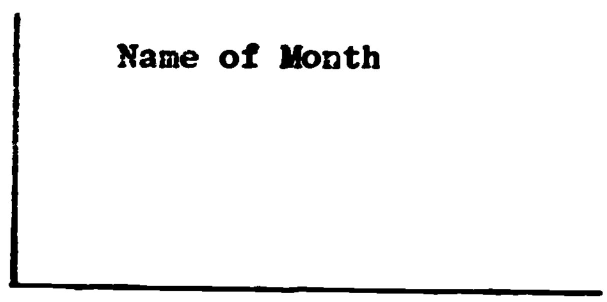
Degrees of Temperature

Days of the Month

See if you can detect any relationship between the temperatures on successive days. What kind of relationship (if any) do you find? Is this relationship such that you could predict the temperature on any day by knowing the temperatures of the immediately preceding days? How accurately could you estimate the temperature of a day, if you knew the temperatures of the day preceding and the day following? How much daily temperature change occurs? To what extent do daily temperatures furnish an example of apparently patternless change?

Now for each month, plot the daily temperatures on a graph in the form of a curve showing the number of days during the month when you recorded each particular temperature:

Number of days



Temperatures

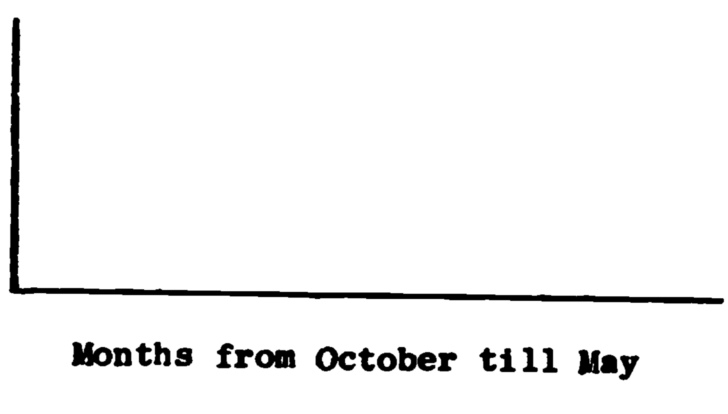
Is there a "piling up" or mode for any particular temperature? What was the most common daily temperature during the month? What was the range of variation? How closely do your results approximate a normal curve? Try plotting the daily temperatures with intervals of one degree, two degrees, three degrees, five degrees. By which method do you get the nearest approximation to a normal curve? Why?

To what extent can apparently patternless changes or variations of any kind be expressed in the forms of a normal curve or warped curve? Why? What causes the difference between normal curves and warped curves? What are warping factors? Are the apparently patternless changes or variations really patternless?

Calculate the average (mean) temperature for each month. What is the relationship of the mean to the mode (the most frequently recorded temperature)? Why?

Now make a graph of the successive mean temperatures of all the months from October till May:

Mean Monthly Temperature



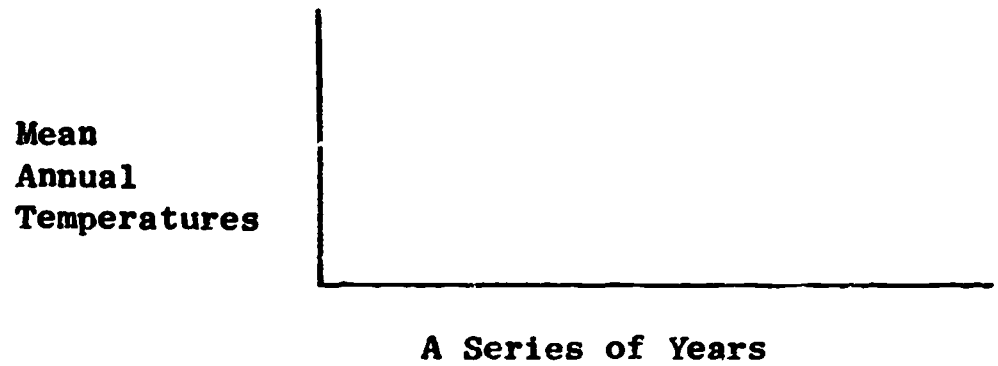
Months from October till May

Is the result a gradient? Why? Compare the gradient for fall with the gradient for spring. Do you see a pattern of directional change? Could you estimate the mean temperature for a particular month if it were missing? Compare this with the situation which you found in the case of the successive days of a particular month. Why do you think there is a difference?

Would you be justified in saying that the apparent lack of pattern among successive day-to-day temperatures within a particular month was due to the short period of observation, and that this daily patternlessness gives way to a directional pattern when there is a longer period of observation?

What do you think would happen if you were to show on a graph the successive mean temperatures of all of the months of a year? What would be the relationship of the seasonal gradients to one another? What is cyclic change? Is this a further kind of patterned change? How is directional change related to cyclic change in this case? Does this relationship also have something to do with the length of the period of observation? Why? What patterning factor is operating here?

If you studied all twelve months of a year, you could, by averaging, obtain a mean temperature for the whole year. Then, if you studied a series of years you could represent on a graph a series of such mean annual temperatures:



What kind of year-to-year change would you expect? Would it appear patternless? Would it appear directional? Would it appear cyclic? What are climatic cycles? To what extent do we have evidence for their existence? What does the length of our period of observation have to do with our knowledge of climatic cycles?

Follow-Up:

How does the behavior of daily, monthly, seasonal, and annual temperatures relate to the Idea of Consistency and Uniformity?

What is the relationship between apparently patternless change, directional change, and cyclic change? How is it concerned with the length of time during which we are able to carry on observations? Let us try to set up a mental model to illustrate this relationship?

Imagine an intelligent animal, able to observe and record observations, belonging to a species with a life span of only 30 days. It would see 30 day and night cycles pass during its lifetime. It could be able to see only one complete lunar cycle, or parts of two such cycles. (This cycle of phases of the moon from full moon to full moon requires 28 days to complete.) At whatever season of the year our animal lived, however, day-to-day temperature changes would appear to it as patternless. Only by reading the historical records of its species would an individual be able to get some idea that directional change in daily temperatures took place with the seasons, and that an annual cycle of temperature changes recurred regularly over a period of twelve or so of its generations.

It might try to understand these longer directional and cyclic changes by comparing them to the directional changes in the appearance of the moon which constitute the lunar cycle that is observable during its lifetime.

Now imagine an intelligent creature with a lifetime of about six months. It would live through several lunar cycles, and would be able to observe the directional change of daily temperatures through a couple of seasons. The annual temperature cycle, however, would be to it as the cold winters and hot summers of the last century, supposedly remembered by our grandparents and other old people, are to us. The historical records of the species would show that these cycles, which they themselves were not able to observe directly, had occurred regularly in the past.

Now we come to ourselves. We have no trouble relating the apparently patternless, daily temperature changes to the directional changes which we see in the seasons, and to the annual seasonal cycle. These all lie within our range of experience. There is some indication, however, that young children may be less able to deal with the concept of the seasonal cycle than older people, and that primitive people dealt with it less readily than people who keep historical records. Some primitive people used the lunar cycle rather than the annual cycle to measure time. Possibly they understood this shorter cycle more readily. For us, climatic cycles, recurring at intervals of many years or many centuries, or even longer periods, are a subject of research and are somewhat controversial. How do you think climatic cycles would appear to a creature with a life span of 1,000,000 years?

Idea of Cause and Effect C.2.

Idea Brdige: Why Do Things Happen?

People generally expect events to have identifiable causes. They are unhappy or uneasy if they see something happen for which they cannot find a cause. If a book falls, it does so because it was dislodged from its position, or because it was dropped. It your car stops, there has to be a reason (cause).

If an automobile accident occurs, it may be because the driver lost control. This in turn, may have been caused by the condition of the road, mechanical failure of the car, lack of skill, or sickness, or drunkenness on the part of the driver, or perhaps some other definable cause. Sometimes these causes are the result of still other causes, each dependent on another. This fixing of responsibility for automobile accidents may be the basis for complicated legal problems, which have to be settled in a court, because they involve payment of damages and insurance claims, and possibly even imprisonment of the driver.

Sometimes when causes result in clearly definable and even measurable physical events, the causes themselves are not measurable, and may even be difficult to define or identify: "He dropped the book because he was startled." "He struck the man because he was angry." "He voted the Republican ticket because he has always been conservative in politics." "He joined the club because he had friends who were members of it." Sometimes people seek simple causes, when really the causes are very complex and involved.

We all think in terms of cause and effect, but a scientist deals with physical and material causes which result in physical and material effects. He prefers to deal with causes and effects which are quantifiable and measurable. Insofar as possible, he limits his studies to such causes and effects.

We need to distinguish, however, between natural scientists (physicists, chemists, biologists, geologists, astronomers, meterologists, et cetera) who deal with problems in nature, and social scientists (sociologists, political scientists, historians, et cetera) who deal with problems of human society. Which do we usually mean when we talk about science and scientists? What about causes and effects in the social sciences? To what extent are causes and effects in the social sciences quantifiable and measurable?

Are there some sciences that are borderline between the natural sciences and the social sciences? What about psychology? Anthropology? (It is possible to distinguish between physical anthropology and social anthropology.)

What are the humanities? Do they fit into the picture?

LABORATORY EXPERIENCE C.2.a.

Force and Motion

Introduction:

Although we use the word "car" more frequently than "automobile," the latter is an interesting word. The prefix, "auto-" comes from the Greek word autos meaning "self." The root word, "mobile" comes from the Latin word mobilis from movere meaning "to move." Therefore, the word automobile means self-moving. Is this possible? Does the automobile really move by itself? What does cause it to move? Can you name anything that really moves by itself? What about you? When do things move?

Materials and Equipment:

Block of wood 2" x 4" x 4"

2 screw eyes

Spring scales

Sandpaper

Smooth paper

Collecting Data:

Put a screw eye into opposite sides of a block of wood. Put a spring scale into each screw eye. Pull with a force of 8 oz. on each scale. What happens to the block of wood? Increase the force on one scale to 10 oz. What happens to the block of wood? If the "pulls" on the scales are equal, the pulls are said to be balanced forces. If the pulls are unequal, they are said to be unbalanced forces. Which kind of forces cause motion?

Lay the block of wood on a piece of sandpaper and on a piece of smooth paper. Use unbalanced forces. Why are you needing more force to cause motion on the sandpaper? What is friction?

What is the force that causes objects to fall to the earth if a force isn't pulling up?

Why can't a man push a wall down? What is the force that must be overcome? What do we mean by inertia? Why can a bulldozer push the wall down?

Dangle the block of wood from the scale. With how much force are you pulling upward? Why doesn't the block move upward? What is the force that balances your force?

What other natural forces are there? What about adhesion? cohesion? centripetal force? centrifugal force?

Follow-Up:

Force is a vector quantity. A vector quantity is one which has both direction and magnitude. I pulled up with 2 pounds. The bulldozer pushed forward with two thousand pounds. A model that is used for vector quantities is an arrow. The length of the shaft represents the magnitude, and the tip shows the direction. If $\longrightarrow$ represents a force of two pounds to the east, how would you represent six pounds to the east? To the west? You can also show motion with arrows because motion is a vector quantity. It has both magnitude and direction. A force of 2 pounds up and 2 pounds down will not cause motion because they are balanced forces. To show this with arrows:

$$\uparrow + \downarrow = 0$$

A force of two pounds up and a force of one pound down will raise an object. This can be shown:

$$\Bigg\uparrow + \downarrow = \uparrow$$

Use arrows in equations to represent balanced forces showing no motion. Do the same with unbalanced forces and show the amount and direction of motion.

How can you show two forces pulling at right angles? The motion that results?

LABORATORY EXPERIENCE C.2.b.

Chemical Reactions

Introduction:

You are familiar with many chemical reactions that occur in nature: iron rusts, silver tarnishes, a bright new copper penny soon becomes corroded. Is there a common cause for all such reactions, or are there many different cause and effect relationships involved?

Materials and Equipment:

Pencil

Paper

Periodic chart or table of the chemical elements

Platform balance

Steel wool

Matches

Collecting Data:

When we did atomic models in Laboratory Experience B.3.a., we examined a Periodic Chart of the Elements. Let us go back and examine it again, and see if we can find something in the structure of atoms of different elements that may be the cause of chemical reactions.

Using the Periodic Chart, draw models* of atoms of lithium, sodium and potassium. How are they similar? How many electrons are there in the outer shell of each one. How could these atoms attain a complete outer shell? There are two ways. See if you can think of both of them. Which one do you think would be the more likely to occur?

Try models of beryllium, magnesium, and calcium. How are these atoms similar? How could these atoms attain a complete outer shell? Try copper and silver. Do all of these have few or many electrons in their outer shells? Does the generalization that you made in connection with lithium, sodium, and potassium apply to all of these elements as well? All of them are called metals. Make a general definition of metals in terms of whether their atoms have few or many electrons in their outer shells.

Place a piece of steel wool (a finely divided metal: iron) on a platform balance, and carefully balance it. Light the steel wool with a match, and burn it. Be careful that none of the steel wool or the substance that results from the burning is lost through being blown or brushed away. What happens to the balance? Why? What chemical element in the air is involved in the burning?

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*The type of atomic model described in B.3.a. is called a Bohr model, after the Danish scientist who devised it.

Draw a Bohr model of an oxygen atom. How does it differ from a metallic atom? If a metallic atom has a few electrons in its outer shell, and oxygen has a few unfilled places for electrons in its outer shell, would this suggest a reason why iron would combine with oxygen, and the way in which it would do so?

An iron compound frequently found in nature is pyrite. This is often called "fool's gold," because of its supposed resemblance to gold in appearance. It is composed of iron and sulphur. The atomic number of sulphur is 16. Does the outer shell of sulfur have places for the electrons which are in the outer shell of iron? How would you draw a model for a molecule of iron sulfide?

When electrons are transferred from the outer shell of one element to the outer shell of another, they are said to be loaned and borrowed. Atoms which are combined in this way are said to be held together by ionic bonds. Not all atoms which combine chemically are held together in this way. Some atoms share electrons. Hydrogen and oxygen do this in forming a molecule of water (See Laboratory Experience B.3.d.) In such cases atoms are said to be held together by covalent bonds.

Draw a model of a hydrogen atom and a helium atom. What is meant by an inert gas? Why is helium an inert gas? Why was hydrogen used in many of the first dirigibles? Why is it not used now? Why is helium used instead?

Why is gold jewelry less likely to tarnish than silver jewelry? What makes stainless steel stainless? Why?

LABORATORY EXPERIENCE C.2.c.

Superstitions

Introduction:

Are you superstitious? Do you feel a little bit uneasy when a black cat crosses the road or sidewalk in front of you? Why? What about a white cat? If a black cat is a bringer of bad luck, shouldn't a white cat be a bringer of good luck? Would there be any way you could test this? How would you go about it? Would you have to define what you mean by "bad luck" and "good luck" in order to do this? How could you go about quantifying and measuring "luck?" Wouldn't you need to do this in order to test a hypothesis about the relationship of luck to the color of the cats that cross your path? What about other superstitions? What others could you possibly test?

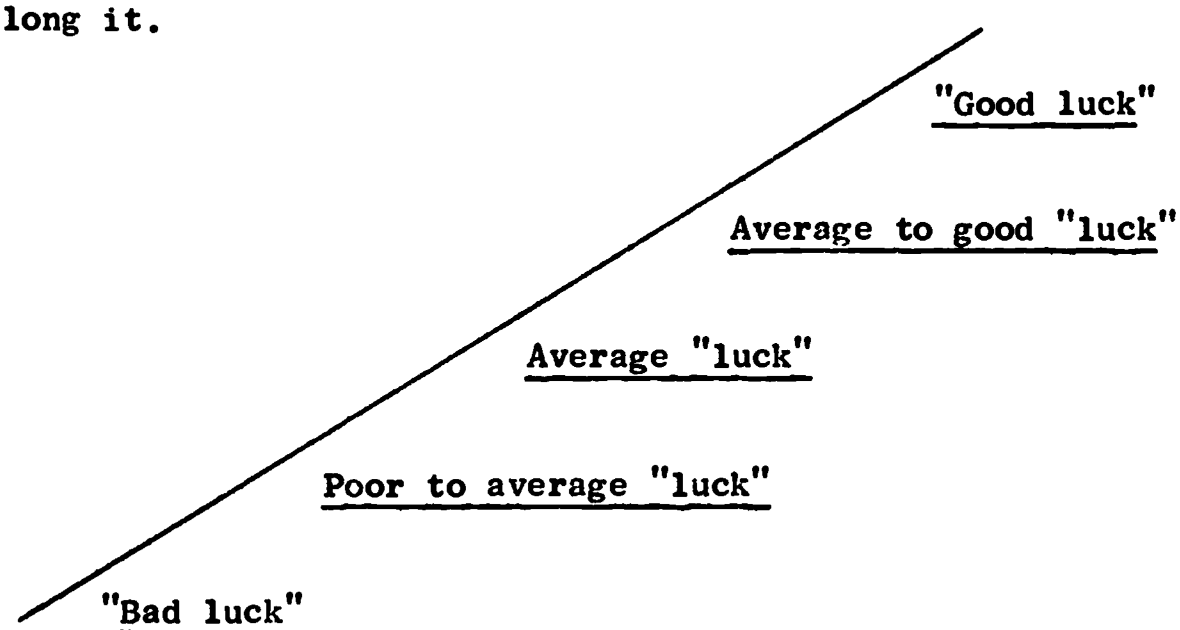
Materials and Equipment:

None.

Collecting Data:

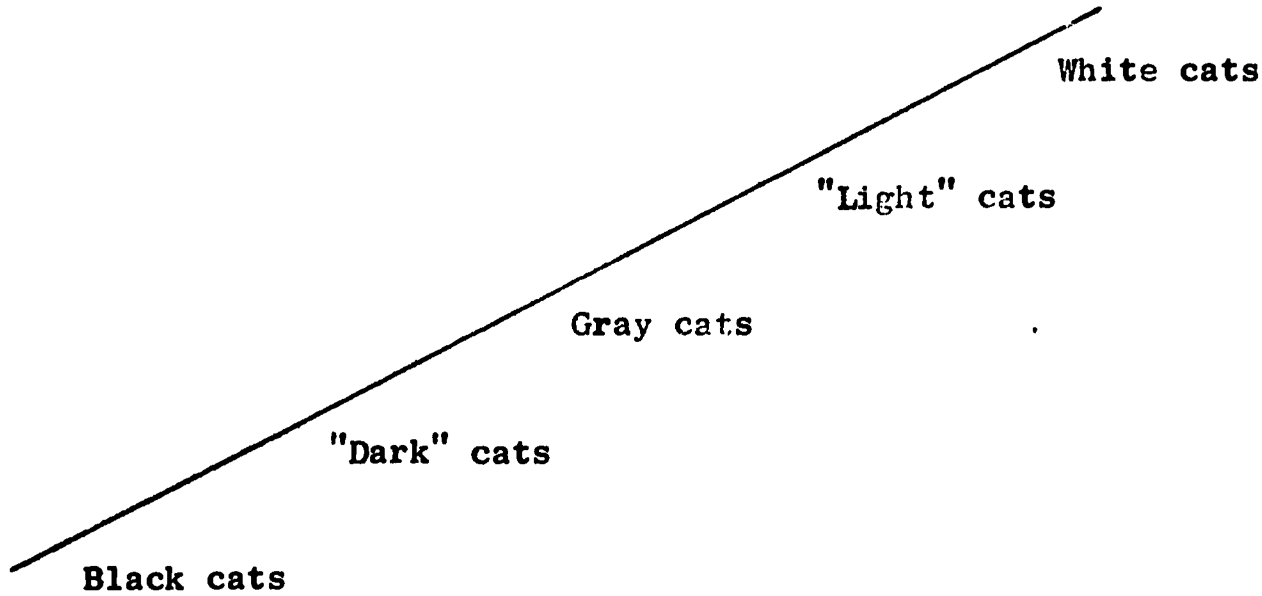
By means of group discussion and decision, set up a definition of "luck"--- "good luck," and "bad luck." Write your definition(s) on the chalk board.

Do not limit your consideration to only good luck and bad luck. Think of "luck" in terms of everyday experiences as occurring along a gradient from very bad to very good (unfortunate to fortunate; unpleasant to pleasant). Think of specific experiences which lie at different points along this gradient. Do this as a group. In this way you will be better able to come up with a meaningful list of experiences. Put your gradient on the chalk board, and indicate the experiences along it.



Is there any point on the gradient at which you can say definitely that good luck ends, and bad luck begins? Try to devise a means of quantifying and measuring luck, for example ("positive" luck, and "negative" luck).

Now set up a similar gradient based on the colors of cats, with black cats at one extreme and white cats at the other. Place other cat colors between black and white on the gradient on the basis of relative "darkness" and "lightness": (Place various kinds of spotted cats at the points where you think their colors would "average out.")



Is there any point on the gradient at which you can say definitely that dark (black to lighter) cats give way to light (lighter to white) cats? Try to devise a means of quantifying and measuring the relative lightness or darkness of cat colors.

Set up a observational procedure which should show if any relationship exists between path-crossing by black cats (or dark cats) and the occurrence of "bad luck" as you have defined it.

For purposes of this experience assume that white cats (or light cats) are bringers of "good luck." Set up a similar observational procedure which should show if any relationship exists between path-crossing by white (or light) cats and the occurrence of "good luck" as you have defined it. Note: In order to increase the number of observable cases, you may consider any "sighting" of a black (dark) or a white (light) cat as a case of "path-crossing."

Now by including all of the experiences which you have during a set period (for example, one day, or one week), and all of the cats observed during the same period, try to determine if there is any relationship between the "goodness" or "badness" of the experiences, and the "lightness" or "darkness" of the cats observed during the same period.

Follow-Up:

What steps in the foregoing experience did you find it difficult or impossible to do? Why? How much of the "method of a scientist" were you able to apply?

Does the foregoing experience constitute a serious attempt to test scientifically the possibility of the existence of a cause-effect relationship between cats and luck? Is it worth while to consider seriously such a possibility? Why? Or why not? How could such a relationship operate if it existed?

Is it worthwhile to consider the possibility that any superstitions (or other old beliefs) might have some basis in fact? Why, or why not? Can you think of some other superstitions (or old beliefs) that it would have been easier or more worthwhile to examine, than the one having to do with the colors of cats? What specific superstitions or beliefs? How would you have investigated them? Is it possible that believing in a superstition might act in some cases as a cause to produce the expected effect?

Idea of Parsimony C.3.

Idea Bridge: How to Resolve Dilemmas

Scientists prefer simple and material explanations of phenomena, rather than explanations that are complex, or that involve non-material factors.

In cases where available data are limited or incomplete, and either of two possible hypotheses will serve to explain the situation equally well, a scientist chooses the simpler of the two possible hypotheses. If, however, accumulation of further data gives support to the more complex hypothesis, the scientist must necessarily accept the more complex hypothesis and discard the simpler one.

In cases where a material and mechanical explanation is possible, and another explanation involving a non-material factor or cause is also possible, a scientist chooses the material, mechanical one. For example, a scientific person who sees a curtain moving doesn't look for a ghost, but for a breeze, or something else material which has moved the curtain. An explanation for the Grand Canyon, as being made when an angry god threw a thunderbolt, is completely unsatisfactory to a scientist. The Colorado River is a material means by which erosion is occurring and therefore is acceptable to a scientist as the means by which the canyon was formed. He may suggest the existence of a yet unknown material cause by way of explanation for a phenomenon rather than accept a non-material one.

Nevertheless, a scientist will maintain an attitude of objectivity and tentativeness with regard to all possible explanations, simple or complex, material or non-material, until all possible data are in.

LABORATORY EXPERIENCE C.3.a.

Origin of the Earth

Introduction:

Ever since earliest man looked into the heavens, he has asked questions: "What is the moon?" "How far away is it?" "Why does it change shape?" "Why does it shine?" "How old is it?" "Who made it?" He has asked similar questions about the stars, the sun, and the earth.

Myths and legends were the efforts of these early peoples: Greeks, Norsemen, Indians, and others, to answer their own questions.

In 1658 Archbishop Ussher of Ireland announced that he had carefully studied the genealogies and life spans of Biblical characters and had computed the age of the earth. He announced that the earth was created in 4004 B.C. Joseph Lightfoot, Chancellor of Cambridge University in England, set the exact date as Sept. 19, 4004 B.C. This date was believed by most Christians, and it was considered heresy to think the earth was more than about 6000 years old.

However, when scientists looked at the delta of the Nile River, and studied the annual deposition of silt, they concluded that it would take more than 6000 years to deposit a delta of that size and extent. They began to ask questions rather than accept conclusions based on little data.

Modern scientists continue to ask more and more questions, even as they find the answers to some of their questions. They continue to search for simple, material answers. Supernatural forces, or forces different from those at present working on the earth, are discarded. Complex answers are examined carefully and discarded for simpler answers whenever possible.

Mythical Stories of Creation:

There were many mythological explanations of the origin of the earth. Every primitive culture attempted to explain the things that they could not understand by the action of gods and legendary figures.

The Chaldeans thought that in the beginning chaotic darkness hid a waste of waters. Heaven and earth had not yet been made. Every living thing came from the primeval ocean. First the great gods, Lahmu and Lahame, arose. Anu, god of heaven, came forth later. He was followed by Enlil, a mysterious deity, and Ea, the lord of wisdom. Tiawith, monster of the deep, had a son named Mummu. Enlil had a son named Bel-Merodach, who became the creator of the world. Tiawith and Mummu were very jealous of Bel-Merodach, and prepared to wage war against the gods of heaven. This was the beginning of the conflict between good and evil.

There are many confused and contradictory Egyptian legends about the creation of the universe. One makes Ra, the sun, emerge from an egg, sail a boat upon the ocean, and create the world and its inhabitants. Sometimes Ra is the sacred beetle Scarab, and other times Ra is a falcon. Another legend attributes the creation to the "magic arts and power" of Thoth, the wise chief moon god, whose voice "called forth the world from nothingness."

The gods and goddesses of the Greeks and Romans will live forever in the masterpieces of art, music, and literature. These divinities lived on Mt. Olympus, which was the center of the world. In the dawn of time the god Chaos reigned, and earth, waters and air were in confusion. The earth was not solid; air was not transparent; and water was not fluid. This disorder could not last. Aethera (light) and Hemera (day) sprang up and formed the skies. Their child was Eros (love). Eros brought into being Gaea (earth). Gaea was heavy and sank under the heavens. Pontus (sea) supported her. Pontus and Gaea had three children. Uranus (time) and Gaea had six children. When these children, who were all gods and goddesses, decided to create living things in the world, they gave the job to Prometheus and Epithemeus. Epithemeus gave so many gifts to other living things that there were no gifts left for man and woman, who were made of clay by Prometheus. Prometheus got assistance from Minerva, the goddess of wisdom. With her help, he lighted a torch from the chariot of Apollo (the sun) and gave man the gift of fire. This made man superior to all other animals.

The Fan Tribe of Africa have an interesting cosmic myth. Before the beginning of time there was nothing but a trinity god: Nzame, Nhere, and Nkwa. These three made everything. They chose the sky as their dwelling, and gave the earth to Fam, the first man. Fam was immortal like the gods. He became too powerful, however so the gods imprisoned him in a hole, and burned off the earth in order to start again. They then created Sekume and Mbonwe, the New People. These consisted of two parts: Gnoul, the body and Nsissim, the soul. They could see the Death Bird. Meanwhile, Nam escaped from the hole, and has tormented the children and children's children of the New People ever since.

The Japanese myth is that heaven and earth were shapeless, and floated in water. Heaven formed first, then earth. Heaven and earth together gave birth to a First Parent. From this First Parent came seven generations of divine beings. Izanagi and Izanami, members of the seventh generation, possessed a celestial spear. Standing on the Bridge of Heaven (the rainbow), they thrust this jeweled spear into the water, and stirred it. The islands of Japan were the result.

Norse myths center around a gigantic,fiery-tempered ice-monster named Ymir. His children were the forces of evil. Buri and Borr, the forces of good, were freed from great blocks of ice by A dhumbla, the Nourisher, a cow. After a long struggle between the forces of evil and the forces of good, Borr carried away Bestla, a giantess, the daughter of one of the forces of evil. To them were born three powerful hero-gods: Odin, Villi and Ve. They began to conquer the forces of evil. They used Ymir's icy flesh to fashion the earth which they called Midgard (Middle Garden). They made the hills from his bones, the trees and vegetation from his hair, the sky from his skull, and the clouds from his brain. To hold up the dome of the sky, they made four dwarfs, one for each corner. They made these from maggots that fed on Ymir's flesh.

American Indian myths differ from tribe to tribe. Coast tribes thought the earth floated on the waters like a raft. Plains tribes believed the earth was a round, flat plain with a sky-tent encircling it like a tepee. The Rocky Mountain Indians thought that stone giants held up the sky. Plains Indians worshippped a Thunderbird and a great Horned Serpent that went writhing across the sky.

There are many, many other myths about creation. Every nation and tribe had faith in good gods, and lived in terror of evil gods. These gods had made earth, the waters of the sea, and the heavens above.

Read the biblical story of creation in Genesis, chapters one to four. Use any version or translation of the Bible that you wish or that you have available. How is the biblical story similar to other stories of creation? How is it different? What similarities do you find in all of the creation stories? What kinds of differences? How did the local environment influence the creation stories? Why did scientists try to find other explanations for the origin of the earth and the universe? Why are none of the creation stories satisfactory from the standpoint of science? Consider them from the standpoint of the Idea of Parsimony.

Scientific Theories of the Origin of the Earth and the Solar System:

Look for paperbacks and other references dealing with scientific theories of the origin of the solar system, and their historical development. Look for them in your school library, in bookstores, and in a public library. Your search for them and location of them is a part of the problem involved in this laboratory experience.

Read about the following scientific theories of the origin of the earth and of our solar system. Watch for ways in which these theories have been modified as new observations were made, and new data were available to be interpreted. Add information from your reading to the brief sketches of the theories given here. Try to understand as much about them as you can.

1. About 200 years ago Georges-Louis Leclerc tried to explain the origin of the solar system by a Collision or Planetesimal Theory. He said that two stars (our sun and another star) collided. They threw off great lumps of hot matter which were set in rotation. These lumps united as they cooled to form planetesimals ("little planets"). The planetesimals, in turn, joined together to form the planets and their satellites (moons).

   Is this a material explanation? Is it simple or complex? Could you accept it just as it is? Why or why not? Would matter from colliding stars be solid lumps, or dust, or gas, or some of all of these? Would it be hot or cold? Would such matter unite to form larger lumps, or would it be dispersed into space? Why or why not?

2. Immanuel Kant and Pierre LaPlace had a different idea. Working separately, they developed the Nebular or Cloud Theory. According to this, clouds of gas and dust were slowly revolving in space. As they cooled and shrank they revolved faster and faster. Rings of matter were thrown off. Each of these rings condensed into a planet which then continued to ratate or its axis and to revolve around a central mass. This central mass condensed to form the sun.

   Is this a material explanation? Is it more simple or more complex than the Planetesimal Theory? Do all planets rotate in the same direction? In what direction does the earth rotate, west to east, or east to west? Are there any planets where the sun appears to rise each day in the west? Why? How is this related to the Nebular Theory? Does it support or contradict the theory? Is there enough gravitational attraction between gas particles or dust particles to make rings condense into planets? If so, why did they condense into planets and not into denser rings?

3. In the early part of the present century Sir James Jeans in England and Thomas Chamberlain and Forest Moulton in the United States discarded the Nebular Theory and revived the Planetesimal Theory in a modified form. They said a gigantic tide was raised on the sun by the gravitational attraction of another star which passed close to it. The tides detached giant, arm-like extensions from the sun. These then condensed to form planets.

   How is this Tidal Theory a modification of the original Planetesimal Theory? Do the same objections apply to it. Why, or why not?

4. In 1943, Carl Weizsacker, a German physicist, proposed the modern Dust Cloud Theory. He said the sun condensed from a mixture of gases and dust. Some matter remained outside, and formed a gigantic rotating envelope. Lumps of planetary material in the envelope became larger and larger. It took about 100,000,000 years for the lumps to accumulate into planets. The surfaces of the planets were heated by the bombardment of the lumps coming together. The planets became extremely hot, and then cooled. How does this theory differ from the Kant-LaPlace Nebular Theory. Is it more simple or more complex?

5. Gerard P. Kuiper has recently modified Weizsacker's Theory. He says the sun and planets were cool when they were formed. The condensation of the sun finally caused it to begin radiating energy. The planets were heated by radioactivity. An American chemist, Harold Urey, says the temperature of the earth, in the final stages of accumulating lumps, was probably no more than 200° Centigrade.

6. In 1956, an English astronomer, Fred Hoyle, proposed a different kind of theory. He suggested that one of a pair of binary (or double) stars exploded. The other member of the pair (our sun) remained intact. The explosion of the star threw most of its matter into deep space. A small portion of it, however, in the form of gas, dust, and larger particles, was held by the gravitational attraction of the sun. Most of this condensed into planets, satellites, and other members of the solar system. Some remained uncondensed, and this formed the cosmic dust and meteorites which are found in space between the planets, and which may constitute a hazard for space travelers.

What are binary stars. Are there any of these in the universe today? If so, how numerous are they? Are stars ever known to explode? What is a nova? How frequently do novas appear? What objections are there to Hoyle's Theory?

Why have there been so many theories about the origin of our solar system? Why can't we find a completely acceptable theory? What relation does each possible answer have to the possible (or probable) occurrence of other solar systems, and other worlds like ours, in the universe?

What is indirect evidence? How does it differ from direct evidence? What methods do scientists use to collect evidence concerning the origin of the earth and the solar system? What new methods are available now for collecting evidence that were not available 50 years ago?

Which of the above theories is the most simple? The most complex? Which one is more generally accepted by scientists? Why?

Theories of the Origin of the Universe:

Until the middle 1920's theories of origin were concerned largely with the origin of the solar system, the sun and its family of planets. Scientists did not know enough about the universe as a whole to be aware of its nature and extent, or to attempt to determine its origin.

In the middle 1920's, however, Edwin P. Hubble discovered that our star group or galaxy, in which our sun is only one of possibly 100 billion stars, is one of millions of more or less similar galaxies scattered throughout known space. Furthermore, he discovered that all of these galaxies are moving away from one another at constantly increasing velocities. The farther away they are, the greater the velocity. What is a spectroscope? How is a spectoscope used in determining this movement of the galaxies. What is the Doppler shift?

Presumably the velocity of continues to increase with increasing distance until it reaches the velocity light, 186,000 miles a second. According to Einstein's Theory of Relativity, this is the greatest velocity which it is possible to attain. Certainly we could not see the light from a galaxy traveling away from us at this velocity, since the velocity of the light coming from it toward us would be exactly canceled out by the velocity of the source of the light moving away from us.

Hubble's discovery made it necessary for scientists to widen their problem from the nature and origin of the solar system to the nature and origin of the universe as a whole. On the basis of what we know at the present time, there are two possible explanations. We do not yet have sufficient evidence, however, to enable us to accept either of them to the exclusion of the other.

1. If the theory of universal expansion means only that the galaxies are getting farther part, it should be possible to project the process backward to a point in time at which our present universe began with a kind of explosion of a relatively small, extremely

dense mass. Presumably, this contained all of the matter which now makes up all of the galaxies, stars and other bodies in the universe.

2. On the other hand, if universal expansion is a property of space itself which carries the galaxies along with it, space has no real "center." The expansion appears to be taking place in all directions from any point in space where the observer may be located. This is comparable to the fact that, when you are inflating a toy balloon, all points on its surface are moving away from any particular designated point. You can try this out, and watch it happen. Why don't you do so?

   Matter in the form of galaxies must be assumed to be constantly "disappearing" as the galaxies attain the speed of light and "wink out" in the ultimate distance, therefore, it must also be assumed that new matter is constantly "appearing" somewhere in space in connection with its expansion. Since hydrogen is the simplest chemical element, and therefore the most basic form of matter, it is assumed that new matter appears in space in the form of new hydrogen atoms. Hydrogen is the most abundant element in the universe (slightly over 50 per cent). It would appear that the new hydrogen might be formed into more complex chemical elements, then into cosmic dust, and ultimately into new stars and galaxies which would "flow outward" with increasing velocity toward ultimate extinction.

   This explanation implies that the universe we see is a kind of "continually flowing fountain" of galaxies and stars.

Each of these two possible explanations has come to form the basis of one or more theories of the origin of the universe. Fortunately, for people who are not astronomers, both points of view have been championed by scientists who are able to write in easily readable, non-technical style. Their writings have been published in popular, paperback books.

The first explanation has given rise to what has sometimes been called the "Big Bang Theory" or, as a more dignified title, the Evolutionary Theory. (This must not be confused with the Theory of Organic Evolution of living things.) The Evolutionary Theory of the origin of the universe has been set forth particularly by George Gamow of George Washington University. According to this theory, the entire universe arose from the explosion of a dense lump of matter called ylem, consisting probably of densely packed neutrons, and not much bigger than the earth.

The second possibility has given rise to the Continuous Creation or Steady State Theory of origin. Its principal advocate has been Fred Hoyle of Cambridge University in England. The general outlines of this theory, involving the perpetual expansion of the universe, and the perpetual renewing of it through the addition of new hydrogen at the "center" has already been set forth. More complex chemical elements are formed from the hydrogen. These form cosmic dust which condenses to make larger particles and lumps, and finally galaxies, stars and planets. These move outward with ever-increasing velocity until they finally attain the speed of light and disappear, while new ones form and take their place.

A variant of the Evolutionary Theory is called the Oscillating Universe Theory. It constitutes an attempt to face the twin problems of "What was there before the "big bang?" and "What will be the ultimate fate of the universe?" This theory has been championed by Ernst J. Opik of Armagh, Northern Ireland. It assumes a periodic expansion and contraction of the universe, like the alternate stretching and releasing of a rubber band. Expansion continues to an ultimate point, and then a corresponding contraction sets in. This, in turn, continues until a point of ultimate density is reached, and a new expansion takes place with the formation of another set of galaxies, containing new stars and possibly new planets like our own. Presumbly, under this theory, the alteration of expansion and contraction could go on indefinitely.

Which of the three theories that have been outlined is the simplest? Which makes the fewest assumptions? Which best meets the requirements of the Idea of Parsimony? Which one of the theories best meets the requirements of the Idea of Consistency and Uniformity (Unit C.1.)? Which is the easiest to believe? Why? Which one is held by most scientists?

Follow-Up:

If you wish to investigate further these modern theories of the origin of the universe, you will find a number of excellent paperbacks available which deal with them.

Read the following:

1. "Introduction," pp. XI-XIII, and "Conclusion," pp. 134-136, in The Creation of the Universe, by George Gamow, A Mentor Book, the New American Library MD214, 1952.

2. Chapter 6, "The Expanding Universe," pp. 93-115, in The Nature of the Universe, by Fred Hoyle, A Signet Science Library Book, the New American Library P2331, 1960.

3. Chapter 1, "The Universe, Geometry, and Relativity," pp. 11-46, Chapter 2, "The Expansion of the Universe," pp. 47-79, Chapter 6, "The Evolutionary Theory," pp. 131-160, Chapter 7, "The Theory of Continuous Creation," pp. 161-180, and Chapter 8, "Discussion of the Theories," pp. 181-206, in Modern Theories of the Universe, by James A. Coleman, A Signet Science Library Book, the New American Library P2270, 1963.

4. "The Expanding Universe: Its Origin and Fate," pp. 114-124, in the Oscillating Universe, by Ernst J. Opik, A Mentor Book, the New American Library MD289, 1960.

5. In all four books read any additional material which you find helpful and interesting. Try to understand it as best you can. (Everyone finds some of this material difficult to understand, so do not be discouraged.)

6. Consult any additional references that you wish. The following paperbacks are suggested for additional reading:

   a. Frontiers of Astronomy, by Fred Hoyle, A Signet Science Library Book, the New American Library T2309, 1955.

   b. The Birth and Death of the Sun, by George Gamow, A Mentor Book, the New American Library MD120, 1952.

   c. The Unity of the Universe, by D.W. Sciama, A Doubleday Anchor Book, Doubleday and Company, Inc., A247, Garden City, New York, 1961.

How does the fact of the expanding universe (Hubble's discovery) present a problem from the standpoint of equilibrium in the universe? Why is it necessary for us to think of the universe as being ultimately in a state of equilibrium? How does each of the theories attempt to deal with the problem in such a way as to present a picture of equilibrium? Does each of the theories do an equally good job of presenting a picture of equilibrium in the universe? Why or why not?

How does each of the theories measure up in terms of the basic scientific assumption of uniformity? Do they measure up equally well? Why or why not? How is uniformity related to the idea of equilibrium?

What is entropy? Why has it been called "the running down of the universe?" How does it appear to be related to the continuous expansion of the universe? How does it appear to be related to the one-way flow of time? How does the one-way flow of time appear to be related to the expansion of the universe? What would appear to happen to time in a pulsating universe? What would appear to happen to entropy? Would this seem to present a barrier to acceptance of the pulsating theory?

Science fiction stories are written about time travel as well as space travel. What do you think about the possibility of time travel as compared to that of space travel? Why?

Under the Theory of Relativity, matter and energy are basically equivalent. Matter can be changed into energy, and energy into matter. The energy released in the explosion of a nuclear bomb (A-bomb or H-bomb) comes from the conversion of a very small amount of matter into energy. Conversely, in a cyclotron, a very small amount of matter is "created" by converting energy into matter. How is this related to the ideas involved in the theories of the origin of the universe which have been presented? Is it related to each of the theories, or to only one? If only one, which one? Why?

Again under the Theory of Relativity, as the velocity of an object approaches the velocity of light, its mass approaches infinity, and time (for it) approaches zero. Also the object which is moving becomes flattened in the direction of travel. As the velocity of light is approached, this dimension of the object also approaches zero. No one, however, not even the mathematicians who arrived at this theory, can imagine this condition of infinite mass, zero time, and two-dimensional volume! No object has ever been observed to travel this fast. Assuming, however, that these conditions are correct, how are they related to the ideas involved in the theories? Are they related to each of the theories, or to only one? If only one, which one? Why?

All life on earth is dependent on energy from the sun which is fixed into organic material (carbohydrates, proteins and fats) by the process of photosynthesis. After passing through a series of organisms, the stored energy is dissipated into the environment. (Green plants are eaten by herbivorous animals, which are eaten by carnivorous animals, and finally, all waste materials and dead bodies are broken down by the action of colorless plants which act as decomposers.) If it were not for the continual input of fresh energy from solar radiation, all life on earth would cease. Energy use is a one-way street.

This ultimate dissipation of energy is true also of the energy which we use in carrying on various physical processes. How is this related to entropy?

In terms of the theories of origin which have been presented, is this "one-way" aspect true of the entire matter-energy picture in the universe? Or is there an ultimate equilibrium if the picture is considered in sufficiently broad terms? Is the answer to the above question equally applicable to each of the theories or only to one? If only one, which one? Why?

LABORATORY EXPERIENCE C.3.b.

Origin of Life: The Story of an Idea

Introduction:

When we try to arrive at a definition of life, we find it hard to list things that living organisms do, that at least some non-living things do not do, even though to a lesser extent, and perhaps in a different way. For example, we may say that living things move. So do papers in the wind. So do pieces of wood in a stream. But we say that living things move by themselves. So do automobiles----So do airplanes. But automobiles have motors in them, which use outside energy. Animals use outside energy, too. Besides, do all living things move? How about plants? They are alive, and they do not appear to move. We know, however, that plants do move. They move slowly, growing, stem upward, roots downward, leaves unfolding and turning outward, the whole plant possibly turning in relation to the sun. Flowers open, tendrils grasp wires and string, and serve as holdfasts.

It is a very confusing problem, this business of defining or describing life as compared to non-life. Perhaps a combination of characteristics or behaviors may serve to define life: (1) ability for self-motion, (2) ability to take in food and eliminate waste products, (3) ability to respond to stimuli, (4) ability to grow "from the inside," (5) ability to reproduce, probably others. Yet every one of these is carried on to some extent at least, and in some understandably related way, by something which is non-living. Some machines take in "food" in the form of a source of energy such as gasoline. After all, an animal's food serves as a source of energy. Machines may also eliminate waste products, as an automobile's exhaust. Indeed, an animal can be called a "living machine."

Many electronic devices, such as self-opening doors, respond to stimuli. Crystals grow, though they do this by addition of new material on the outside, rather than on the inside, as living organisms do. A small fragment of a crystal, when placed in a solution of the parent material, will "reproduce" a new crystal.

There is one form of life, the viruses, which possess only one of the characteristics that we think of as belonging to living matter. They can reproduce (or replicate themselves) when they are placed in a suitable environment. They are not able to move. They do not take in food and eliminate waste materials. They do not respond to stimuli. They do not grow from the inside. Although their process of replication bears some resemblance to the way in which a fragment of a crystal develops into a larger crystal, it also is related to the process of reproduction in more complex forms of life. Viruses probably represent life at its simplest --- So simple that for a long time it was questioned whether they were really living at all.

How Did Life Begin?

Without attempting to define life too closely, we must ask ourselves how life came to be. The religious explanation, of course, is that it was divinely created by a single special or unique act. "Unique" means something that happened only once, and is outside the usual order of things.

Without either denying or defending this possibility, (because he can believe whatever he wishes about it), a scientist must think beyond it. Since special creation is not capable of being either tested by experimentation or analyzed scientifically, a scientist simply "tables" it---He leaves it outside of consideration, and goes ahead to try to see how life came about. He is concerned with questions of "How?", not "Why?", or "Who was responsible?"

A scientist is driven to ask "How?" because of his basic belief in a describable and explainable world. He cannot accept the separating off of a part of the natural world, and being told that he is forbidden to investigate it. He believes that all material and measurable phenomena have material causes, and that it is his job to try to discover these causes. Since life is a material and measurable phenomenon, with a reality in terms of physics and chemistry, he must seek its origin.

Two Possibilities

Exploration of the question of the origin of life is very ancient. Even the old Greeks had theories about it. There are really only two possibilities: Either (1) there has always been life, if not on earth, at least somewhere in the universe, or (2) life has originated and can originate from non-living materials. The first view is called biogenesis----Life can come only from pre-existing life. The second view is called abiogenesis----Life can originate from non-living materials.

Here is where the Idea of Parsimony enters the picture. It is much simpler to believe that life has, and perhaps still can originate from the non-living, than it is to believe that living things, even very simple ones, have always come only from other living things like themselves. Even though biogenesis can readily be demonstrated, and has been shown to be true in specific cases time after time by experimentation, belief in abiogenesis will not disappear.

The reason that this is so,is that it is difficult to get away from the notion that life had to originate sometime, somewhere, somehow. Belief in abiogenesis has reappeared again and again. To believe otherwise would force us to assume that life had no origin. This is less simple, less easy to accept, than to believe that life had a natural origin.

A Long and Mixed-Up Story

These two theories, abiogenesis and biogenesis, have been championed in various forms by different philosophers and researchers all through the history of science. The form that abiogenesis took originally was a belief in the spontaneous generation of life. According to this belief, frogs in the spring came from the mud at the bottom of ponds; parasitic worms developed spontaneously in the intestimes of the animals they were found in; and maggots were produced by decaying meat.

One man in the 1600's,Jean-Baptiste van Helmont, a Belgian physician, wrote a recipe for producing mice. He said it could be done in 21 days by putting a dirty shirt and some grains of wheat (a piece of cheese would work as well) in a pot or box, and setting this away in a dark place where it would not be disturbed. He believed that the active principle in producing the mice was the human sweat in the shirt. Undoubtedly, he tried out his recipe, perhaps many times, and got mice everytime.

(You could try this)

Do you think it would be worthwhile to try out van Helmont's recipe? Why, or why not? Even if you do not have a place where you could do it with dirty clothes, and grains of wheat (or cheese), and mice, you could do it with garbage and flies, at least in warm weather. Undoubtedly, it would work just as well, and it would not take 21 days.

If you were to try it, how would you do so in order to get results that would be valid from the standpoint of a scientist? Would a scientist do it exactly as van Helmont did it? Why or why not? What was wrong with the way van Helmont did it?

Although it would be perfectly possible to try this out, it is probably just as well to simply think it through, and discuss it. Don't you think so?

A number of early scientists, up to and including Louis Pasteur in the middle 1800's, did try out the theory of abiogenesis scientifically. Their results, however, always led them to adopt the opposite point of view: biogenesis.

One of the earliest experiments designed to test abiogenesis was that of Francesco Redi, an Italian physician in the 1600's. Contrary to the view held by most others of his time, he did not believe that maggots arose spontaneously in decayiny meat. Following is a modified quotation from his account of his experimentation published in 1688:

"Although it is a matter of daily observation that great numbers of worms are produced in dead bodies and decaying plants, I am inclined to believe that these worms all arise from other living things, and that the putrified matter in which they are found has no other function than that of serving as a suitable place where the eggs are deposited, and in which the worms find nourishment. Other than this, I do not believe that anything alive is ever generated in the decayed matter.

"Having considered these things, I began to believe that all worms found in meat are derived directly from the eggs of flies, and not from the decaying of the meat. I was still more sure of this belief because I observed that, before the meat grew wormy, flies had hovered over it, of the same kind as those which later developed from the worms that lived in it.

"Belief would not be justified without the support of experiment. Therefore, in the middle of July, I put a snake, some fish, some eels from the Arno (a river nearby), and a slice of milk-fed veal, in four large, wide-mouthed flasks. I closed and sealed these flasks. Then I filled the same number of flasks in the same way, except that I left these open.

"It was not long before the meat and the fish, in the second set of vessels, became wormy, and flies were seen entering and leaving the vessels at will. In the closed flasks, however, I did not see a single worm, although many days had passed since the dead flesh was put into them. Outside on the paper cover there were a few deposits, or sometimes a maggot that eagerly looked for some crevice by which it could enter and get nourishment. Meanwhile, the different things placed in the flasks became putrid.

"Not content with this experiment, I tried many others, at different seasons, using different vessels, In order to leave nothing undone, I even put pieces of meat underground. There, although they remained buried for weeks, they never developed worms. Worms always appeared, however, when flies were allowed to alight on the meat."

What was Redi's hypothesis? See if you can state it in your own words. Why did Redi not believe in the spontaneous generation of maggots? Why were maggots and decaying meat good material for him to use for experimentation? What other things might he have used? Why was Redi's approach more scientific than van Helmont's. How is experiment related to control? Try to define "experiment" and "control" on the basis of what Redi did. How did Redi's work form a basis for belief in biogenesis as opposed to abiogenesis?

(You can try this:)

Working with flies and decaying meat would not be very practical in a junior high or middle school classroom or laboratory. In the first place, the adult flies would not be available to deposit the eggs on the meat. Then, too, the odor of the decaying meat would probably be offensive. It is possible, however, to carry on an experiment similar to Redi's, using fruit flies (Drosophila melanogoster) which can be obtained readily and inexpensively from any biological supply company.* In order to carry on this experiment, however, you probably should have a storeroom, or preparation room, which is kept heated, where the fruit flies can be allowed to fly free without being too great a nuisance. They are small but persistent. You have undoubtedly seen them around decaying fruit in the summer.

Materials and Equipment:

Fruit fly culture. Obtain a culture of wild type Drosophila melanogaster from a biological supply company.

Bananas (one or two)

Cake of yeast

10 wide mouth bottles (2 3/4" high, with mouths 1 3/4" in diameter). These also may be obtained from a biological supply company, since they are the kind generally used as culture bottles for growing fruit flies. (You can use the small glass jars that commercial baby foods are sold in, if the wide mouth bottles are not available. They are approximately the same size.)

Spoon

Pipette (medicine dropper)

Cotton for plugging the bottles

Hand lens

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*Examples are General Biological Supply House, Inc., 8200 South Hoyne Avenue, Chicago, Illinois, and Carolina Biological Supply Company, Burlington, N.C.

Procedure:

1. Allow the Drosophila to multiply in the original bottle until it is well-filled with them. Then release them in the room where the experiment is being carried on.

2. Put a layer of mashed-up banana in the bottom of each of the 10 bottles. Mash up a small amount of the yeast (about the size of a pea) in water in a spoon. Squirt a little of this yeast water mixture with a pipette onto the surface of the banana in each of the bottles.

3. Plug the mouths of five of the bottles with cotton. Be careful that the cotton plug does not touch the layer of banana in the bottom of the bottle. Be careful also that no flies get into the bottles while you are working with them.

4. Leave the other five bottles open. Put all 10 of them together on a shelf or table. Do not leave any banana exposed in the room, other than that in the bottles. Why?

5. Watch all 10 bottles for two or three weeks. Look particularly for maggots burrowing in the mashed banana on the inner side of the glass. You will need a hand magnifier for this. Do you see any maggots in the open bottles? In the closed bottles? Watch the maggots and see if you can determine what happens to them.

Note: The fruit flies do not feed on the banana directly. They eat the yeast cells that grow on the banana. The banana in the open bottles might become innoculated naturally with wild yeasts from the air, but innoculating it artificially with yeast suspension insures a food supply for the flies.

Discussion:

How is this experiment like Redi's experiment? Do you believe that it is a parallel case? Why, or why not?

This is really not a true laboratory experience, even though it includes an experimental set-up and a control. It is an illustrative experience rather than a laboratory experience, because no problem in involved. You know how it is going to come out, or at least how it is supposed to come out, before you do it.

Abiogenesis received a new lease on life as a result of the work of Anthony van Leeuwenhoek, a Dutch spectacle maker and pioneer microscopist, who lived in the late 1600's and early 1700's. He made the first careful observations of protozoa (one-celled animals) and bacteria. Leewenhoek himself did not believe that the little organisms he saw arose by spontaneous generation, but many other biologists did. They believed that even though larger animals such as mice and flies come only from other mice and flies, microscopic forms of life must surely arise from the decaying plant material in the water in which they are found.

(You can make a hay infusion)

Materials and Equipment:

Hay or dried grass

3 wide-mouth jars, no larger than gallon size.

Compound microscope

Slides

Cover slips

Pipettes

Vessel for boiling the hay or grass

Source of heat

Procedure:

1. Draw enough tap water to fill your three jars. Boil it for 30 minutes.

2. Cut or break the hay or grass into pieces not more than two inches long.

3. Boil the hay or grass for 30 minutes.

4. Fill each jar approximately two-thirds full (loosely packed) with the boiled hay or grass. Divide the liquid in which the hay or grass has been boiled equally between the three jars. Then fill each jar to within about two inches of the top with the tap water that has been boiled.

5. Leave the jars open and exposed to the air.

6. Observe any changes that take place in the jars over a period of two to three weeks.

7. If the liquid becomes cloudy, and a scum appears on the surface, put two of three drops of it, including some of the scum, on a glass slide, cover with a cover slip, and examine with a compound microscope under both low and high power.
   Note: If you have never used a microscope, ask your teacher to show you how to do so before you attempt to use it.

8. What kinds of organisms do you see with the low power? With the high power? Are they moving? How many different kinds of living organisms are there? Ask your teacher to help you try to find out what they are.

Discussion:

Where did these organisms come from? If we believe in biogenesis, they must have come from other living organisms like themselves.

But this seems impossible, since the plant material was boiled, and the water was boiled, and when the mixture cooled, it was exposed only to air. The air must therefore have contained inactive stages of the organisms, and these in turn must have come originally from other living organisms like themselves. The inactive stages grew into active stages when they fell out of the air into a suitable environment: the hay infusion.

Why was the material boiled? What are spores? Where do they come from? How are they carried in the air? How long can they live in the air? Can they grow or reproduce in the air? Why, or why not? Do we breathe them into our lungs when we breathe air? Do they have any relation to diseases? What diseases?

In 1711, a French scientist names Louis Joblot studied hay infusions in relation to abiogenesis and biogenesis. He believed that if air containing the inactive stages of organisms is prevented from coming in contact with boiled hay infusion, the organisms will not develop in it. He tested his hypothesis by means of an experiment which he described as follows:

"I boiled some hay in water for half an hour. I then put equal quantities of the hay and the water in which it had been boiled into two vessels of the same size. Before the infusion had cooled I closed one of the vessels. The other vessel was left uncovered. After several days, organisms appeared in the open vessel. There were none in the closed vessel. It was kept for a considerable time to see if organisms appeared, but none did."

(You can try this:)

Repeat Joblot's experiment. See if you can get the same results. Use the same equipment and materials you used before in making the hay infusion.

What is the control in this experiment? What part does it play in the experiment? How is the experiment related to the problem of abiogenesis and biogenesis. What conclusion can you draw as a result of it?

All careful experimentation up to this time indicated that microorganisms could not develop in a sterilized medium unless it is exposed to open air. (Note: A medium is an environment in which organisms will grow if they are seeded there.) Nevertheless, the believers in abiogenesis still had an argument which seemed to be unanswerable. They thought that there was something in air which had not been heated that made it possible for life to develop spontaneously.

What more natural than to assume that unmodified, unheated air contained a principle that could give rise to life? After all, it was a good deal simpler to believe in the existence of such a principle, than it was to believe that somehow all microorganisms came from pre-existing microorganisms, and so on back through endless time.

The only way to prove that this simple explanation was wrong was to find a way to expose a sterilized medium to unheated, unmodified air, and still prevent spores (in which biogenesists believed, but abiogenesists did not --- and which no one had ever seen), from entering it.

Louis Pasteur, a French chemist in the middle 1800's, invented a way to do just this. His research had taken place with yeasts rather than protozoa and bacteria. In testing for abiogenesis, he prepared infusions and placed them in flasks with long necks that curved first downward and then upward. He boiled the infusions in the flasks until the steam came out of the openings. Then he left them open, so that unheated air from the outside could enter them. He thought that any spores of microorganisms carried in the air would be trapped in the curved necks of the flasks, and would be unable to enter the medium.

Pasteur was right. His hypothesis proved to be completely correct. No life forms appeared in the sterilized flasks with the open, curved necks. The infusion medium which they contained remained sterile indefinitely.

Why did the "unheated air" argument advanced by the abiogenesists make "good sense" until it could be disproved? Do you think that the "active principle" which the abiogenesists believed to be carried in the air was thought of as being something material (something that could be weighed, measured, or discovered by analysis)? Or do you think it was something non-material, like a "spirit" or "vital force"? What does this have to do with its relationship to science as we know it now? Do you think that the biogenesis vs. abiogenesis controversy, as it existed in Pasteur's day, could have lasted into our time, even if Pasteur had not carried on his successful experiment?

Was Pasteur's success due to his superior logic and superior analysis of his problem or to his superior technique? Is it possible that loose plugs of cotton in the mouths of his flasks, through which the "unmodified" outside air could pass, would have achieved the same results for Pasteur as the curved necks of his flasks did? Why or why not? Microbiologists now use cotton plugs to close culture tubes. Do you suppose this fact is related in any way to Pasteur's problem? Why? How do you think it might be related? Can you think of a way to set up an experiment to try this out? Geneticists who raise fruit flies in culture bottles also use cotton plugs. Do You suppose the fruit flies need a certain amount of air circulation which they can get in this way?

The Century After Pasteur

You might presume that Pasteur's experiments, dealing with the most minute forms of life that had been discovered up to that time, would have put to rest permanently the case for abiogenesis. Actually, it did so for about fifty years. The principle "All life comes from pre-existing life," ruled supreme and unquestioned until near the end of the century.

Of course the question which followed: "Where did the first life come from?" remained unanswered, if the possibility of divine creation were left "on the table." Had life always existed? Did germs of life float in space between the planets and galaxies? This idea was seriously advanced in the form of the cosmozoa theory.

Something like the cosmozoa theory is alive in our time in the form of suggestions that life spores may float in space along with the cosmic dust which we know does exist in space. Can you suggest a way in which the existence of such life spores could be tested experimentally? Is anything of this kind now being thought about, or being done?

Toward the end of the 1800's, the so-called "filterable viruses" were discovered. These are disease-causing agents that are so small that they can pass through the pores of filters made of unglazed porcelain. We now know a great deal about the viruses and the diseases that they cause.

We know that the active material that viruses contain is either deoxyribonucleic acid (DNA) or ribonucleic acid (RNA). These nucleic acids are able to replicate themselves, that is, they can make other molecules like themselves, when the materials which they contain are present in the medium.

DNA is the substance which makes up the genes which carry heredity in all higher organisms. In a very real sense, a virus is a kind of "free gene." RNA in higher organisms is always associated with DNA. DNA and RNA together are responsible for the making of proteins. Proteins are the most important compounds in living matter.

Most, if not all proteins act as enzymes. Enzymes are responsible for carrying on all of the chemical reactions that go on in living matter. They start chemical reactions, and regulate the rate of reactions. Life has been described as " a bundle of enzymes in action."

All proteins consist of a relatively small number (about 22) kinds of building blocks called amino acids. These are compounds containing carbon, hydrogen, oxygen and nitrogen. Plants can manufacture them, while animals must get them from the good they eat.

For the first time in history of science, life can now be defined in terms of chemistry. If we now know the chemicals from which living matter is put together, would it be possible for us to put these chemicals together and produce life? This possibility must seriously be considered in our time.

If life can be analyzed into simpler and simpler chemical terms, can we, by going back far enough in time, come to a point where simple chemical compounds that were the forerunners of life, were produced through the agency of natural forces? What were the environmental conditions of the primitive earth? If such pre-life chemicals developed at that time, could they have survived? Could these simple pre-life compounds then have evolved into true life forms that, in turn, gave rise to the life forms of today? Scientists cannot give definite answers to any of these questions, but modern attempts to find answers for them have made it possible for the ancient doctrine of abiogenesis to re-appear in a new form.

Follow-Up: The Modern Theory of the Origin of Life

In the late 1920's an English biologist, J.B.S. Haldane, suggested a way in which the natural origin of life might have come about. In the late 1930's a Russian, A.I. Oparin, worked out such a theory in detail. During the 1940's, an American biochemist, N.H. Horowitz, worked out a similar theory independently.

In the 1950's, Harold Urey and Stanley Miller, at the University of Chicago, set up an experiment in which they circulated water containing the gases methane (CH_4), and ammonia (NH_3), so that it passed an electric spark. This was believed to duplicate some of the conditions of the primitive earth. After a week, the solution had changed color. When it was analyzed it was found to contain a great variety of molecules normally found in living matter. Among these were several amino acids.

Finally, in the late 1950's, Sidney Fox heated a mixture of 18 or 20 amino acids to the melting point, and then allowed the mixture to cool. When he did so, he found that some of the amino acids had united to form chains. They did this in a way similar to the way in which they unite when they form proteins.

It is a long way from amino acids to viruses, which are the simplest form of life that we know. DNA, however, which is the ultimate "stuff of life," has been broken down and rebuilt, and may soon be synthesized in the laboratory from its basic parts.

Did life arise in the beginning of the world from simple compounds of carbon, hydrogen, oxygen, and nitrogen? Were these formed spontaneously through the coming together of still simpler compounds like methane and ammonia? Was this possible under the environmental conditions that existed at that time? Did the first pre-life compounds then evolve toward increasing complexity? Were molecules finally produced like the nucleic acids, which could "make more of themselves?"

Here we are back to abiogenesis again! We have come a long way from van Helmont, but we have a simple beginning; simpler even than frogs from mud, maggots from meat, or even protozoa and bacteria from decaying hay. And we are no longer faced with the difficulty of believing that life has always existed.

LABORATORY EXPERIENCE C.3.c.

Pebbles, Cobbles and Boulders

Introduction:

When the early settlers came to New England, they found the surface filled with sand, pebbles, cobbles and boulders. They were interested only in clearing their fields of cobbles and small boulders, so that they could cultivate the soil and plant crops. At the same time geologists in Europe found sand, pebbles, cobbles, and boulders at the surface, but they were interested at that time only in bedrock and fossils.

When settlers moved westward they observed that the northern part of the country also had sand, pebbles, cobbles, and boulders, but those who crossed the Appalachians farther south found soil with almost no cobbles and boulders to be cleared from the land.

Scientists called the boulders of the north erratics. What does this word mean? Why was it appropriate for these boulders? Some pioneers called them "lost rocks." Why was this a good name for them? When valley walls and/or excavations in the north were examined it was discovered that the pebbles, cobbles, and boulders were not of the same material as the bedrock. In the south the few stones that were found were obviously pieces of the bedrock.

Scientists in Europe and America began to ask questions: Where did the erratics found in the north come from? When did they come to these areas? How were they brought to their destination?

Procedure:

Let us examine several hypotheses to determine which one is the most simple, and if the most simple is the most reasonable. What data support each hypothesis? What data contradict each hypothesis? Does the Idea of Parsimony apply?

The erratics demanded the most attention at first. They were in unusual positions. Some were balanced on others. Some were standing precariously on ledges. Some were as large as 60 X 40 X 40 feet and were estimated to weight hundreds of tons. A quartzite erratic in Canada measured 150 feet, and was estimated to weigh 18,000 tons.

Some people sought supernatural explanations. The rocks were thrown in anger by "Mother Nature." They were brought to their present position by the devil. They were "witches' hearthstones." They were tossed around by giants. Since all of these explanations depend on the supernatural rather than the natural, they can be readily discarded. We are seeking simple, material explanations.

A few scientists postulated that the earth had passed through a comet's tail. This is a simple, material explanation isn't it? Why not accept it? Before we can do so, there are some questions that we must ask. Of what does a comet's tail consist? Does the earth ever "pass through" a comet's tail? What would probably happen if it did?

Other scientists said these rocks were shot out of the earth like bombs when something inside the earth exploded. Others blamed earthquakes or other violent movements of the earth's crust. However, when scientists traced the erratics back to their bedrock source, it was obvious they came from the surface and not from the interior of the earth, because many were composed of sedimentary or metamorphic rock rather than igneous rock. What are sedimentary and metamorphic rocks? How do they differ from igneous rocks? How is each kind of rock formed? Sometimes when the source of the erratics was found, it was hundreds of miles from the present location. Any explosive force that could have thrown them that far was unimaginable. Anyway, they would have destroyed any surface on which they fell. Obviously a better explanation was needed.

The explanation which was most widely believed was the Flood Theory. It stated that the biblical flood of Noah's time had worn smooth the surface of the erratics much as stream tossed pebbles are worn smooth. It had also sorted the material as to size, much as streams sort materials, and had then deposited them when the flood receded. Read the story of the biblical flood in the 7th chapter of Genesis. In northern Europe and Britain, this hypothesis was easily believed. Inhabitants along the coasts watched the violence of winter storms and saw what the waves did to rocks. The clay, sand, pebbles, cobbles, and boulders were called drift. But the question had to be raised: Where did enough water come from to produce as much drift as covered the surface of the land in many areas far from the coast? Would forty days and forty nights of rain, such as is described in Genesis, produce enough water?

Many scientists suggested supernatural sources of water such as "heavy rains from another planet," the "breaking loose of lakes," a "wave caused by the earth stopping its rotation on its axis," or a "submergence of the continents". Since these all are unique events or extraordinary happenings, we can discard them as unacceptable hypotheses.

Most scientists accepted the Flood Theory, but they discovered some features among the drift which they could not explain. They found long, straight, parallel striations (scratches) in the bed rock. They also found polished rocks. At the surface or beneath the drift they found rocks that looked as if they had been polished in a lapidary. A third finding consisted of faceted pebbles. These stones had flat polished faces that were like those cut by jewelers on diamonds. The Flood Theory could not explain these phenomena because water can not scratch, polish, or facet rock. Scientists added another ingredient to the water---icebergs. They saw great chunks of ice floating in the ocean. Often there were boulders frozen in the ice. The scientists said that when the flood (The Flood Theory was still believed) threw icebergs up onto the land, the embedded materials scratched, polished, and faceted other rocks.

Many scientists refused to accept the Iceberg Theory because they said an iceberg bobbing about in water could not cut straight striations, Polished rock, and faceted stones could not be found where icebergs had come ashore today. The presence of striated rock near the top of the Alps also made the Iceberg Theory hard to believe. How much water would be necessary to carry icebergs to the top of such high mountains?

Karl Schimper, a German botanist, was the first to suggest that erratics had been carried by ice, not water. He wrote a poem in 1837 entitled "Die Eiszeit' ("The Ice Age") in which he suggested a long period of cold weather in Europe. Jean de Charpentier and Ignaz Venetz - Sitten visited the glacier fields of the Alps. Charpentier accepted the Glacier Theory for mountain areas.

Louis Agassiz of Switzerland knew Charpentier but did not accept his Glacier Theory. In 1836 they visited the Alps glaciers together. When Agassiz had examined the evidence: moraines where glaciers were stationary, fields of drift, striations and polished rocks, he accepted the Glacier Theory.

Louis Agassiz visited the Jura Mountains and found the same kind of evidence. In 1837 he gave a speech to the Helvetic Society of Natural Science which is accpeted as the first public explanation of the Glacier Theory. Geologists in the audience were shocked and angry.

Agassiz later made extensive studies of glaciers both in Europe and America. He studied areas of northern Europe and North America and found the same evidence of glaciers that he had found in the mountain areas of Europe. His Glacier Theory spread, and by the time of his death in 1873, it was widely but still not unanimously accepted by scientists.

Why were many scientists still accepting the Flood Theory? Is it more simple? Does the Idea of Parsimony apply here?

Follow-Up:

Look up about Louis Agassiz in an encyclopedia or historical geology. Read about his explorations of glaciers.

Read about the Pleistocene Epoch in North America.

Study relief maps of North America to find the location of glacial deposits such as moraines, drumlins and eskers. Are any of these located near where you are?

If you are in a formerly glaciated area, look for striated pebbles and polished rocks. If you are not in a formerly glaciated area look for rounded pebbles in a stream bed. Also try to find evidences of wind erosion.

Study a soil profile to find evidence of either residual or transported rock in your area.

LABORATORY EXPERIENCE C.3.d.

Two Theories of Evolution

Introduction:

Change of living things through time, evolution, is a belief that is very old. Almost everyone who has ever made a systematic study of living things on the earth has come to believe that evolution has occurred. Even the ancient Greeks believed it, or at least their philosophers and other wise men did. With the development of modern science during the past 400 years, many different areas related to living things have been studied. These studies have strengthened scientists' belief in the occurrence of evolution. Some of these areas in which evidence for evolution has been found are the following:

Comparative Anatomy

Anatomy is the study of the structure of animals. Comparative anatomy is the study of the anatomy of animals which appear to be related to one another; comparing them, part with part: their skeletons and their various internal organs.

Certain groups of animals, such as dogs, wolves, foxes, jackals, and hyenas; and cats, tigers, lions, leopards, and cheetahs, are not only similar in appearance but have internal structures that are very similar. They are, therefore, believed to be closely related ("cousins" in a sense).

All vertebrate (animals with backbones), including fishes, amphibians (frogs, toads and salamanders), reptiles, birds, and mammals (animals with hair that nourish their young with milk) have the same basic body plan, and are believed to be more distantly related (more distant "cousins"). The same can be said of other large groups of animals, such as the arthropods (insects, spiders, lobsters, and their kin), and the echinoderms (starfishes, sand dollars, sea urchins, sea cucumbers, and their kin).

Animal "cousins", either close or distant must have had common ancestors, just as human cousins have common ancestors.

Fossils

Present-day animals appear to be descended from creatures somewhat like themselves, of which fossil remains have been found. Fossils are the remains or other evidence (such as footprints) of animals and plants that lived in the past. Most ancestors represented by the fossils are not exactly like their present-day descendants. The degree of difference becomes greater the farther back in time we go. Ultimately, through gradual changes. the ancestors are very different. The ancestors of distantly related present-day groups (dogs, cats, seals, horses, cattle, camels, and deer) are more alike the farther back we go. Therefore we believe that all of these present day animals are related. All of this adds up to the concept of "descent with modification," or evolution.

In general, plants appear to have changed as much as animals have. They appear to be related to one another in about the same way that animals are. We can believe, therefore, that the evolution of plants has taken place in very much the same way as the evolution of animals

Embryology

The embryonic stages of animals in any apparently related group (such as the vertebrates) resemble one another more closely than the adult stages do. The farther back in embryonic development we study them and compare them, the more similar we find them to be.

Physiology

Physiology is the study of functions. It leads ultimately to a study of the chemistry of living matter. Animals which are related to one another have body fluids (blood, lymph) that are chemically similar. The more closely the animals resemble one another physically, the more similar they are chemically.

Geographic Distribution

When animals and plants are studied on a world-wide basis, the distribution of related species is most readily understandable if we consider that they have developed their present-day forms as they have migrated slowly from their ancestral centers of origin. Thus, all different species of oak trees are related to one another. Oaks originated in North America. While there are many kinds of oaks in the United States, very few are found in Western Europe. This is because, to get there by a land route, the oaks had to migrate northwestward across Canada and Alaska, across Bering Strait when it was dry land, and then across Siberia and Russia into Western Europe. Very few of them ever got there, and the ones that did include only the oldest and most primitive kinds.

Collecting Data:

From what has been said in the Introduction, it is obvious that there is very little reason to doubt that evolution (change of living things through time) has taken place. It appears, therefore, that the question, "Has evolution occurred?" must be answered with "Yes." A great deal of evidence from many sources has been collected. All of it tells the same story. Various kinds of animals and plants appear definitely to be related to one another. They appear to be near or distant "cousins," and cousins have common ancestors.

The question "How has evolution taken place?, however, has been much more difficult to answer. There have been two major theories. (A theory is a kind of "big hypothesis," set forth to explain a very large body of data.)

Lamarck's Theory of Evolution

In 1809 a French zoologist by the name of Jean Baptiste Lamarck presented a theory that evolution has taken place through the inheritance of characteristics acquired during the lifetime of the organism because of necessary adjustment to its environment.

For example, the ancestors of the horse strengthened their legs in running to get away from their enemies. Therefore, each succeeding generation of their descendants developed stronger and longer legs, until finally they gave rise to the present-day horse with its long, strong legs. Similarly, the cat developed eyes that can see well in semi-darkness; birds developed wings for flying; seals developed flippers and a body shaped for swimming (as fishes had done long before); and man developed hands for picking things up and holding them and a brain for thinking.

The following is a slightly modified quotation from a book on the history of biology which states Lamarck's theory:*

> The main points in Lamarck's theory may be told very briefly. It is a theory that the evolution of animal life has depended on variations brought about mainly through the use and disuse of parts, together with responses to external stimuli, and the direct inheritance of these variations. His theory is broad and comprehensive. It accounts for the evolution of all living things, plants as well as animals, including man.

Another quotation is modified from Lamarck's own statement of his theory in his book Philosophie Zoologique (Philosophy of Zoology), published in 1809.

"Animals living in any locality keep their same habits as long as their conditions of living remain the same. Because of this, species (kinds) of animals appear not to change during the short time that we are able to observe them. This has resulted in the belief that these species are as old as nature. However, in the various parts of the earth's surface where animals and plants live, the wide variety of locations and climates make environmental conditions which are extremely variable. Therefore, the animals which live in these places must differ from one another. They do this not only because they are complex living organisms, but also because of the habits that each particular kind of animal has to acquire.

"When an observing scientist travels over large parts of the earth's surface, he sees conspicuous changes occurring in the environment. Then he always finds that the characteristics of the species of living things undergo changes which correspond to the changes in the environment.

"The true principles that can be seen in all this are:

1. "Every big and permanent change in the environment of any species of animals causes a real change in the needs of that species.

2. "Every change in the needs of animals makes new activities necessary for the animals to satisfy those needs. These activities result in in new habits.

3. "Every new need, making necessary new activities to satisfy it, causes the animal either to use some of its parts more frequently, and thus greatly develop them and make them grow larger, or else develop entirely new structures to meet the needs.

"In order to learn of the true causes of the great variety of structures and habits found among animals, we have to think about the many different kinds of environments that animals of each species have had to live in, and the fact that these environments are all slowly changing. Because of these changing conditions, the animals have developed new needs, and have changed their habits to meet these needs.

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*From Locy, William A., Biology and Its Makers, Third Edition, Henry Holt and Company, New York. 1915, p. 384.

"We can see how the new needs may have been satisfied, and the new habits produced, if we pay attention to the following two laws of nature:

"First Law. More frequent and continuous use of any organ gradually strengthens, develops, and enlarges that organ, while the permanent disuse of any organ slowly weakens it and makes it less able to function, until finally it disappears.

"Second Law. All of the gains and losses brought about by nature in individuals through use and disuse are passed on through inheritance to the next generation."

Try to apply Lamarck's theory of evolution to humans. In doing this, you will best work as a part of a discussion group, either a committee or team or as a class group. Think of some characteristics in humans that are influenced or affected by use and disuse. Are these characteristics passed on to children in the next generation? What reasons do you have for believing or not believing that they are inherited, at least to some degree? Can you prove your belief? Can you prove your disbelief? How would you go about doing so?

Are there any acquired characteristics which you believe definitely are passed on? Are there any that you think may be passed on, at least to some degree? What acquired characteristics do you believe definitely are not passed on. State reasons for your belief in each case.

Do you think that Lamarck's theory should be (1) entirely discarded; (2) accepted, with some reservations on the basis of modern knowledge; or (3) given the benefit of some doubts, and kept, waiting for accumulation of additional evidence?

Darwin's Theory of Evolution

In 1859, Charles Darwin, an English zoologist, published a book called The Origin of Species, in which he presented the second major theory of how evolution has taken place. He had spent more than twenty years collecting evidence for his theory.

The following is a slightly modified quotation from a textbook of biology which summarizes Darwin's Theory:*

1. "Living organisms tend to reproduce themselves in such a way as to increase their numbers indefinitely.

2. "The numbers of organisms, however, tend either to remain about the same from year to year, or to increase at rates far less than their reproductive abilities would permit.

3. "Consequently, there has to be a struggle for existence. Organisms must struggle with their environment for survival and the opprotunity to reproduce, and many must fail. Elimination of these comes about because of the physical environment, and also because of the living environment (other living organisms: competitors, predators, parasites.)

*From Kenoyer, Goddard, and Miller, General Biology, Third Edition, Harper and Brothers, New York, 1953, pp. 531-532.

4. "All characteristics show variation among living organisms---among individuals of the same species; even among offspring of the same parents.

5. "The organisms that are best adapted, because of their varying characteristics, to meet the conditions of the environment survive (the survival of the fittest), while the others perish.

6. "The characteristics that enable living organisms to survive in the struggle for existence are inherited by the next generation. Therefore, they persist, increase, and become established in nature, while other characteristics are eliminated."

The following statement is adapted from Darwin's book, The Origin of Species.* It follows closely Darwin's own statement of his theory:

"Under changing conditions of environment, living things show individual differences in almost all parts of their bodies. It is also true that if they are left alone their rate of increase is much greater than would be necessary to maintain a stable population. Therefore a struggle for life takes place at any age, season, or year.

"The relationships of living organisms to one another and to their environment are extremely complex. Because of this complexity, it is of advantage for living things to be as different from one another as possible in structure, function, and behavior. It is inevitable that some variations should be better able to contribute to an animal's welfare than others. When such useful variations occur, it is only to be expected that they will have the best possibility of being preserved in the struggle for life. These successful variations will be passed on through heredity, and the organisms which possess these variations will tend to produce offspring which are like themselves.

"This principle of preservation, or survival of the fittest, I have called natural selection---selection by the environment of those variations that are best able to survive. It leads to the improvement of each creature in relation to its environment, living and physical. The results, in most cases, are an advance in organization---the development of more complex forms from simpler forms. Nevertheless, low and simple forms of life continue to survive with little or no change, if their conditions of life do not change, and if they are well adapted to these conditions."

What do you think of Darwin's theory? Which theory, Lamarck's or Darwin's, do you think is the simpler explanation of how evolution has taken place? Which do you think is the more believable explanation? Apart from everything else, which theory would you prefer to believe? Which theory would make it easier to deal with modern social problems? Why? Can you apply the theory of natural selection ("survival of the fittest") to humans? Why, or why not? Can you think of any examples where the theory does apply? Where it does not apply?

Follow-Up:

Selection among living organisms in nature takes place by elimination of the "least fit" in each generation. Therefore, in the long run, the "fittest"

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*Charles Darwin, The Origin of Species, 1859, Chapter IV, p. 128. Reprinted by the New American Library, Mentor Books MC222, 1958.

survive. The "least fit" are those members of a species that are unable to survive under the conditions that the environment presents. They are "not good enough to get by." It is like a game in which those who are not able to compete are eliminated from further competition. Athletics----all kinds of competitive games----are like this. We compete for grades, for social acceptance, to "keep up with the Joneses," in everyday life.

The laboratory experience which is suggested here is a model for natural selection. It is a tournament (like a basketball tournament) to determine which student in the class is able to put together a simple puzzle in the shortest time. Since there will be several "rounds" in the tournament, with the same puzzle being used in all of the contests from the beginning to the end of each "round," the ability to improve the skill involved in putting the puzzle together will play an important part in determining who will be the winner. Possibly some of the skill learned in putting one puzzle together will even carry over to another puzzle which may be used in a different "round."

In each series of contests (each "round"), it is the least skilled that are eliminated. Since this process continues through several series of contests, in the end it is the most skilled, or those who become the most skilled, that survive. This is much the way it is among living organisms in nature.

Materials and Equipment:

Filing cards, 3" x 5"

Tags

Scissors

Envelopes

Ruler

Setting up your model:

1. A simple puzzle should be prepared for each member of the class. All puzzles should be made according to the same pattern. Each one consists of a 3" x 5" filing card cut into ten pieces.

   The ten pieces into which the card is cut should be approximately the same size, and of as many shapes as possible. The cuts, however, must all be along straight lines. It is best to draw the lines lightly with a pencil to indicate the cuts before doing the cutting. The pieces of each puzzle should be placed in an envelope and given to the student, but neither the pieces nor the envelope should be marked in any way.

2. A series of numbered tags, beginning with (1), should be prepared, equal to the number of students in the class. These should be shaken up, and each member of the class should draw a number. This will determine his participation in the first series of contests.

3. Students will contest in pairs. As many pairs may contest at a time as there are umpires to watch them. Students who are not contesting at a particular time may serve as umpires. In each contest the student who gets the puzzle together first is the winner.

4. Each student will contest three times in each series of trials ("round"), For the first trial, the pairs numbered (1) and (2), (3) and (4), (5) and (6), (7) and (8), and following, will contest. For the second trial, numbers (1) and (3), (2) and (4), (5) and (7), (6) and (8), and following, will contest. For the third trial, numbers (1) and (4), (2) and (3), (5) and (8), (6) and (7), and following, will contest. Students losing all three of the contests will retire from the game.

5. The numbers should be collected at this point. The students who are still in the game will draw new numbers in a series beginning with (1). They will then repeat the process in a new "round," each contesting three times in the same numerical order as before. A different puzzle should be substituted for the original one at this point, but all contestants must again use the puzzle.

6. Additional "rounds," following the same pattern, will continue until all students except one have been eliminated. A different puzzle should be substituted at the beginning of each new round. The final remaining student will be declared the winner of the tournament. If more than one class group has been engaged in this laboratory experience at the same time, the "champion" of one class may contest with the "champions" of the other classes for a "grand championship."

How is this experience like natural selection in nature? How is it different? How is it like competition in business or politics? How is it different?

Sum up your learning with regard to Lamarck's and Darwin's theories of evolution. Which do you think is the more likely to describe the way in which evolution has <u>actually occurred</u>? Did the <u>simpler</u> theory prove to be the <u>better</u> theory in this case? Why, or why not?

Do you think that evolution may still be occurring in this way? Why, or why not? Try to think of some examples of situations where evolution may be occurring now.

IDEA-CENTERED LABORATORY SCIENCE

(I-CLS)

Unit C. How a Scientist Expects His World to Behave

TEACHER NOTES

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Unit C. How a Scientist Expects His World to Behave

TEACHER NOTES

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LABORATORY EXPERIENCE C.1.a.

Projecting Our Expectations

TEACHER NOTES

This is a laboratory experience that involves more thinking than doing. There is an Idea to get across: that we expect dependability in our world, and that if you project this dependability backward and forward through time you can account for how things got to be the way they are, and see what they will almost certainly be like in the future. There is also a problem to be solved: how can we see the world around us as a law-bound world when we are so close to it, and so accustomed to it.

This Idea and the problem which accompanies it must be made real to students in language that they can understand, and in terms of experiences that they understand. If it were possible to produce a state of disorientation (being "turned around") experimentally, the problem would be more easily attacked. This state brings home the reality of the Principle of Consistency better than any other experience that one can have.

Since this is not possible, the best that we can do is to point out how we take the Principle of Consistency for granted in everything we do everyday, and then ask the students to try to imagine what the world would be like if it were not so. This again needs to be thought of in terms of everyday experiences.

If it were possible to have the students fly in an airplane at a low altitude over the Appalachians or other old, worn-down mountain range, they could see that long-time geological erosion is like short-term field erosion but on a many thousand times greater scale. Since this is not possible, examination of a relief map will suffice.

Carefully selected (or constructed) motion pictures might help, but it seems that the best way to make the Principle of Uniformity real to students is to have them observe what is available for them to see, and to think and make analogies and extrapolate. This is what the old geologists did. They had no airplanes to fly over mountains nor even automobiles to travel long distances quickly. Yet they arrived at the generalizations that we use now.

Finally the Principles of Consistencyand Uniformity must be tied together. The students must be brought to see that these are the short-term and long-term aspects of the same Idea. Given Consistency projected into the past and future, you have Uniformity.

LABORATORY EXPERIENCE C.1.b.

The Moon and Stars

TEACHER NOTES

This laboratory experience will necessarily have to be done at night, although a visit to a planetarium, if one is available, is an interesting experience for the students, and may be helpful.

If it is possible to arrange a series of night field trips they will furnish a valuable instructional opportunity, but the experience can be carried on in large part by individual students working on their own, and reporting back to the group in the classroom. Such reporting sessions will furnish excellent opportunities for questions --- student to teacher and teacher to students --- and discussion.

It is possible to attain most of the goals of this experience by doing the moon part of it only, but the star parts, either the Big Dipper and Polaris part or both parts, including the Orion and "winter procession" part, will add greatly to the strength of the experience.

This is an inherently interesting laboratory experience, and it is easy to "get lost" in it, and lose sight of the Idea toward which it is directed: Consistency and Uniformity. Do not allow yourself or your students to lose sight of this Idea.

LABORATORY EXPERIENCE C.1.c.

Relationships Among Different Kinds of Change:

Daily, Monthly, and Annual Temperature Changes

TEACHER NOTES

This laboratory experience can actually be done in less time than the entire period from October till May. However, the longer it is continued, the better, and it necessarily must be continued through at least two successive seasons. It should be started at an appropriate time. If necessary, this may be even before the Idea of Consistency and Uniformity is introduced. The observing and recording of daily temperatures, and the representation of these on graphs is an interesting experience which committees of students can be appointed to do. The conclusion of the experience, however, must take place when the Idea of Consistency and Uniformity is being considered, so that its relationship to the Idea can be pointed out.

This is actually a laboratory experience in thinking, and the data must all be assembled before the relationships will become apparent.

LABORATORY EXPERIENCE C.2.a.

For‿‿ and Motion

TEACHER NOTES

The use of arrows to show force and motion is another example of the Idea of Model Making.

The basic concept is that there can be no motion without unbalanced forces. The cause of motion is always unbalanced forces.

You can relate this concept to the movement of animals and the growth of plants. Doing this will furnish an interesting tpoic for class discussion. Here the unbalanced forces on metabolic energy and inertia.

LABORATORY EXPERIENCE C.2.b.

Chemical Reactions

TEACHER NOTES

In this laboratory experience the explanation of how chemical combinations of elements occur to form compounds has been greatly simplified. The cause of chemical combination is shown to be the movement of electrons in the outer shells of elements, especially in the case of metals and non-metals. The complete story of chemical bonds is too complex to be practical to present at the junior high or middle school level. The Idea of a cause-effect relationship, however, is readily apparent.

You should draw Bohr models of atoms on the chalkboard in order to review them. These models themselves, of course, constitute a simplification in terms of some more modern concepts of atomic structure.

LABORATORY EXPERIENCE C.2.c.

Superstitions

TEACHER NOTES

This laboratory experience is not "for real." It is a caricature. It is designed to make students think about something that people do not ordinarily consider worth thinking about. It constitutes a case of "going through the motions" of looking for a cause-effect relationship, even though it is obvious that no such relationship exists. Nevertheless, it is possible to deal with this as a real problem, and attack it seriously. When students do this, it becomes an interesting experience. They will find reasons for taking it seriously.

Why isn't it science? What keeps it from being science? "Luck" cannot be really defined --- much less quantified and measured. Colors of cats couldn't be less related to "luck",even if we could define what luck is! And yet, if one believes that a black cat brings bad luck, this in itself may cause misfortune through affecting one's mental set.

The idea here is to help students to think in terms of cause and effect relationships; and to learn to evaluate situations where no such relationships exist.

If you wish to substitute some other common superstition or belief instead of the color of cats, it is perfectly all right to do so. You may not be able to use the idea of interacting gradients, however, if you do so. You may need to remodel the experience to fit the superstition or belief you are testing.

LABORATORY EXPERIENCE C.3.a.

Origin of the Earth

TEACHER NOTES

The material in this experience is inherently interesting, and some of it appears in science readings designed for students at intermediate grade levels. It is generally presented, however, strictly in narrative form, and without reference to the problems which it involves, or to the ideas which underlie the problems. The intention here is to approach the problem of origin historically and comparatively, in terms of the Idea of Parsimony and finally, the Idea of Consistency and Uniformity.

The simpler materials are presented first. The brief treatment of mythology at the beginning is designed to show man's early concern for the problem of origin, and the general type of answers that he devised. The contrast with scientific answers is clear. The earlier scientific answers were simpler than the later ones, because the later ones had more facts to take into account. Even with the latest, most complicated scientific answers, however, the Ideas of Parsimony and of Uniformity set a standard for judgment.

It is not necessary that the students understand all of the aspects of the theories, or the evidence on which they are based, in order to make judgments concerning parsimony and uniformity. The material is written as simply as possible, and arranged so that the students may go as far with it as they are able. The writers hope, of course, that you, the teacher, will also find the problems interesting.

LABORATORY EXPERIENCE C.3.b.

Origin of Life: The Story of an Idea

TEACHER NOTES

This is an experience in the history of science. The laboratory portions of it are not the portions that would ordinarily be called "laboratory." They are rather the portions following presentations of the work of van Helmont, Redi, Leeuwenhoek, Joblot, and Pasteur, where questions are raised, and the story is opened up for discussion. The questions raised are at all levels. Some can be answered readily; some possibly with difficulty; while some cannot be answered at all, even by those who know most about the problem. Some of the questions probably never can be answered, even with continued research.

This business of questioning is the essence of inquiry, and the basis for the reality of laboratory. Laboratory is problem solving (and problem raising). It is not simply illustrative experience, even though this takes place using the techniques and materials usually associated with laboratory, and at a place and time designated as laboratory.

You should watch your students closely and carefully during this experience, stopping to "translate" when and as necessary, as frequently as necessary, and for as long a time as is necessary. There is nothing here that students at the junior high or middle school level cannot understand, but you must hold their attention on it long enough for them to do so, and you must present it to them in their language. We have tried to do this in the written materials, but you know your students, and you must help.

The illustrative experiences ("laboratory") have the function mainly of serving as attention getters and attention holders. From the standpoint of the continuing story of the theory and its development, these experiences could be left out. The story would be completely logical and intact without them. They serve, however, to break it into manageable parts, and they make it more tangible and interesting.

Infusion cultures are interesting in themselves. You can add the microscopic study of a yeast culture as a parallel or follow-up to Pasteur's part of the story, if you wish. "Growing" a "crystal garden" at this point might serve to show an interesting contrast to the growth of living organisms.*

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*to make a yeast culture:

Prepare a saturated solution of table sugar (sucrose) in water. Innoculate it with a few drops of a yeast suspension, prepared by breaking up a pea-sized portion of a yeast cake in a tablespoonful of water. Allow the yeast-sugar solution to stand over-night in a warm place. Examine a few drops of it on a glass slide, covered with a coverslip, under both low and high power of a compound microscope.

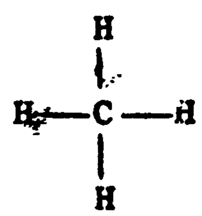
*to make a crystal garden:

Mix:	3 tablespoonfuls of table salt (NaCl)	3 tablespoonfuls of water
	3 tablespoonfuls of liquid bluing	½ tablespoonful of household ammonia (NH_4OH)

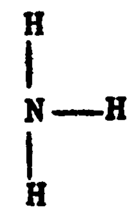
This will make a "grainy" sort of mixture, not a solution. Pour the mixture into a dish over several stones. Allow it to stand. The crystals will begin to form in ten to fifteen minutes.

When you mention methane (CH_4), ammonia (NH_3), and amino acids, it would be well if you put the structural formulas for these on the chalkboard. The students will have learned about structural formulas, and methane in particular, in connection with an earlier laboratory experience under the Idea of Model Making (B.3.b.) Putting these on the chalkboard, however, will give students an opportunity to strengthen the earlier learning, and will give them something tangible to which they can tie their thinking.

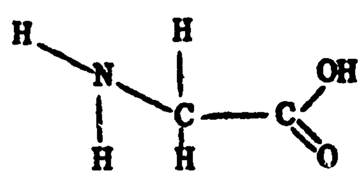
The structural formulas are as follows:



Methane (CH_4)



Ammonia (NH_3)



Glycine, an amino acid

Finally, we have avoided use of the terms autotroph and heterotroph in presenting our story. This was a little difficult, since the Haldane-Oparin-Horowitz Theory of the Origin of Life, which we have presented in simple form, is generally called the Heterotroph Theory. If you wish to introduce the students to these terms, of course you may do so. We attempted, however, to present the story as a story, which we hoped would (with your help) carry its own interest. We suggest that you present it as a story --- a very interesting story --- showing how simplicity (the Idea of Parsimony) battled with complexity (supported up to a very late stage by the results of research), and how simplicity finally won. This resulted because biogenesis, which represented complexity, was unable to answer the question: "How did life originat in the first place?" Logical thinking, supported to some extent by recent research, has finally come up with an answer which, while it is not completely proved, and possibly never can be, is very probably the true answer.

LABORATORY EXPERIENCE C.3.c.

Pebbles, Cobbles and Boulders

TEACHER NOTES

In helping students with this laboratory experience be sure not to let them lose sight of the Idea of Parsimony. It is easy to get involved in the story of glaciation because this is an inherently interesting story. Remember that we are doing this in order to see how in the long run simple material explanations are preferred, unless there is positive evidence to prove the contrary.

This is an excellent laboratory experience to take students into the field, individually, in small groups or to work together or as a class. Field experience here will contribute greatly to how much they get out of this.

LABORATORY EXPERIENCE C.3.d.

Two Theories of Evolution

TEACHER NOTES

Although this laboratory experience goes rather deeply into the problem of evolution, the primary reason for including it here is to lead to an understanding of the Idea of Parsimony. The development of the evolution story in the history of science furnishes an outstanding example of the process whereby an elegantly simple theory, the inheritance of characteristics acquired through use and disuse, which originally was widely accepted because of its simplicity, had to give way to a more complex theory, natural selection, as a basis for evolution.

This took place, of course, because the weight of the evidence, as it accumulated, was all on the side of natural selection. There was nothing wrong with Lamarckism from the scientific standpoint, except that it wasn't true! The scientific world abandoned it with reluctance. Communist science still holds it, but it does so on the basis of ideological rather than scientific grounds. The feeling persists that it ought to be true, but it cannot be because no real evidence has ever been discovered to support it.

It is important for students to realize that a scientist will abandon a simple explanation and take up a more complex one, if the evidence requires it. Even though he expects the world to behave in such a way that it is explainable in simple terms, he has not always found it so.